FISHERY INDUSTRIAL RESEARCH

VOLUME 6 NO. 1

United States
Department of the Interior
U.S. Fish and Wildlife Service
Bureau of Commercial Fisheries

Members of the fishing industry and allied interests who wish to receive FISHERY INDUSTRIAL RESEARCH should write to:

Bureau of Commercial Fisheries
Division of Publications
Bldg. 67, U.S. Naval Air Station
Seattle, Washington 98115

UNITED STATES DEPARTMENT OF THE INTERIOR
Walter J. Hickel, *Secretary*
Leslie L. Glasgow, *Assistant Secretary*
for Fish and Wildlife, Parks, and Marine Resources
Charles H. Meacham, *Commissioner*, U.S. FISH AND WILDLIFE SERVICE
Philip M. Roedel, *Director*, BUREAU OF COMMERCIAL FISHERIES

FISHERY INDUSTRIAL RESEARCH
Volume 6 -- Number 1

Washington, D. C.
MARCH 1970

As the Nation's principal conservation agency, the Department of the Interior has basic responsibilities for water, fish, wildlife, mineral, land, park, and recreational resources. Indian and Territorial affairs are other major concerns of America's "Department of Natural Resources."

The Department works to assure the wisest choice in managing all our resources so each will make its full contribution to a better United States — now and in the future.

COMMERCIAL FEASIBILITY OF IRRADIATING HADDOCK AND COD FILLETS: INTRODUCTION

by

John D. Kaylor and Edward J. Murphy

ABSTRACT

In the studies introduced by this report, three questions were asked: Is a high enough proportion of haddock and cod, as landed in New England, fresh enough to justify their being irradiated? (2) Is the temperature of fish during commercial distribution by common carrier sufficiently low to preserve the quality of the fish? (3) Can haddock and cod fillets be irradiated and shipped on a commercial scale and still exhibit a significantly increased shelf life at iced temperatures? The data collected in the studies indicate that the answer to each of the three questions is "yes."

Glass and Smith (1960)[1] have shown that irradiating food with radioactive cobalt-60 at sterilizing dose levels of 4.5 to 5.6 million rads does not impart radioactivity to the product. In the irradiation preservation of fresh fish, the dose levels used are far below sterilizing levels -- generally less than 300,000 rads. Thus, when fresh fish are preserved by irradiation, they do not become radioactive, so radioactivity is not a problem.

Nickerson, Lockhart, Proctor, and Liciardello (1956) and Carver and Steinberg (1959) have shown that the irradiation of fresh fillets significantly extends the shelf life of the fillets under laboratory-controlled conditions. Although this finding is encouraging to the businessman who might be interested in preserving fish by irradiation, it does not tell him whether the shelf life of fresh-fish fillets irradiated on a commercial scale at low-dose levels of irradiation and shipped under commercial conditions will show an increase that is commercially significant. In short, before a businessman would invest his money in this process, he would have to be shown that the favorable results in the laboratory can also be realized on a commercial scale.

To investigate the feasibility of irradiating and shipping fishery products on a commercial scale, the Atomic Energy Commission has built and the Bureau of Commercial Fisheries has staffed the Marine Products Development Irradiator at Gloucester, Massachusetts (Kaylor and Slavin, 1965).

Although we would like to use this commercial-sized irradiator to investigate the irradiation of all commercially important species of fish, we have had to choose a few species to study initially. Because haddock and cod

[1] R. A. Glass and H. D. Smith. 1960. Radioactive isomer production in foods by gamma rays and X-rays. Stanford Res. Inst. Contract DA19-129-QM-1511. Quartermaster Food and Container Inst., Chicago, Ill., 66 pp.

Authors: John D. Kaylor, *Supervisory Food Technologist*, and Edward J. Murphy, *Food Technologist*, Bureau of Commercial Fisheries Technological Laboratory, Emerson Avenue, Gloucester, Massachusetts 01930.
Published February 1970.

are the most important species in the New England groundfish industry, they were the logical choices.

Until the early 1920's, the fishing industry marketed haddock and cod in the round, but since then, it has marketed them in the form of fillets, owing to the greater demand for fish products in this convenient-to-use form.

Unfortunately, the shelf life of the fillets is short. Kaylor (1966) and Daniel Yankelovich Incorporated (1966) found that the shelf life seldom exceeds 5 days at the retail level. This short shelf life precludes distributing the fillets widely by common carrier, the only way that they can now be transported and still be sold at a relatively low price.

The market for fresh New England groundfish fillets thus is limited to the area shown in Figure 1. If the shelf life could be extended, the market, of course, could be enlarged correspondingly. The New England groundfish industry would then benefit from this larger market, and the people in the new marketing area would, in turn, benefit by being able to choose from a wider variety of fresh fish.

The purpose of the work reported here, therefore, was to determine whether it is feasible to irradiate haddock and cod fillets on a large scale and then ship them by common carrier to distances well beyond present-day markets and still maintain the fillets at a high level of freshness.

We carried out this work in three investigations. These studies were of such a nature that if the first had turned out to be unsuccessful, we would not have undertaken the second, and if the second had turned out to be unsuccessful, we would not have undertaken the third.

To operate, an industry needs, of course, a supply of suitable raw material. Unfortunately, irradiation, like other means of preservation, such as freezing, does not improve the

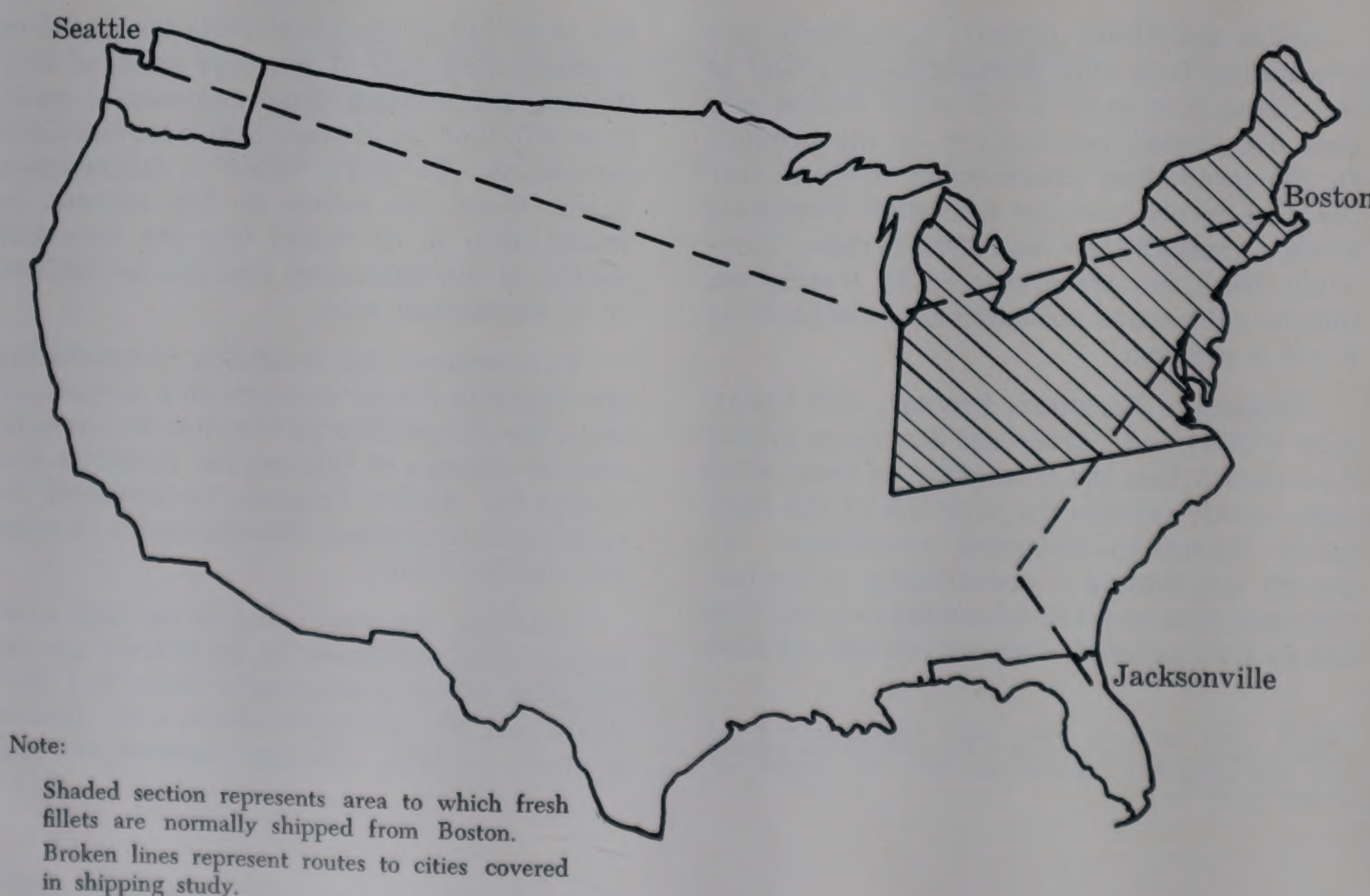


Figure 1.—Map showing routes of shipping studies.

freshness of fish. It merely helps to preserve whatever freshness is present. Furthermore, economics will not permit the industry to irradiate fish of questionable quality. Accordingly, the purpose of the first study was to determine whether a high enough proportion of haddock and cod, as landed, is fresh enough to justify being irradiated.

Fortunately, we could simplify the study. Haddock and cod are handled similarly, so that general conclusions concerning the freshness of one species will apply to that of the other. Historically, Boston, which is located near Gloucester where our irradiator is, has been a leader in the haddock fishery. These facts led us to choose haddock as the species to be studied and Boston as the port in which to study them. The first investigation in the series therefore was to determine the proportion of haddock landed in Boston that are fresh enough for irradiation.

This study showed that 78 percent of the haddock landed was of a level of freshness that will justify treatment by irradiation. Thus, the proportion of haddock and cod suitable for irradiation is more than adequate.

After we found that supply is not a problem, we had to find the temperature patterns of fresh fillets during commercial distribution via common carriers. If these temperatures turned out to be high, the commercial shipment of irradiated fishery products probably would be unsuccessful. Our second study showed, however, that the average temperature of fillets in interstate commerce was less than 40° F. Thus, temperature during shipment via common carriers is also not a problem.

Having now found that supply and temperature during transit are not problems, we had to learn whether haddock and cod fillets could be irradiated and shipped on a commercial scale and still exhibit a significantly increased shelf life at iced temperatures. This final study showed that, under commercial conditions, haddock and cod had an extension of shelf life of 10 or more days longer than the nonirradiated control samples. This extension is great enough to enable industry to ship fish to any sector of the nation and still have enough residual shelf life to permit marketing in the normal manner.

The details of the three studies will be reported in three future papers.

LITERATURE CITED

Carver, Joseph H., and Maynard A. Steinberg.
1959. Effect of radiation pasteurization on the storage life and acceptability of some North Atlantic fish. Commer. Fish. Rev. 21(10): 1-6.

Kaylor, J. D., and J. W. Slavin.
1965. Irradiation - big advance in preserving seafood. Fish. News Int. 4: 147-151.

Kaylor, John D.
1966. Commercial prospects for radiopasteurized seafood. U.S. At. Energy Comm., Div. Tech. Inform., Sixth Annu. AEC Food Irradiat. Contractors Meet., CONF-661017: 14-16.

Nickerson, J. T. R., E. E. Lockhart, B. E. Proctor, and J. J. Licciardello.
1954. Ionizing radiations for the control of fish spoilage. Food Technol. 8(1): 32-34.

Daniel Yankelovich Incorporated.
1966. Cost-benefit study of selected products in Atomic Energy Commission's low-dose irradiation program. U.S. At. Energy Comm., Div. Isotope Develop., TID-NYO-3666-1, 242 pp.

MS. #1969

RECOMMENDATIONS FOR HANDLING AND ICING FRESH PACIFIC HALIBUT ABOARD VESSELS

by

Wayne Tretsven and Harold Barnett

ABSTRACT

The icing of halibut aboard the fishing vessel sometimes is inadequate to minimize the loss of quality during the trip. Observations made of icing and other handling practices aboard halibut vessels serve as the basis for the recommendations suggested here for improving the method of handling. Adhering to these recommendations will help the fisherman land halibut of more uniform quality.

CONTENTS

INTRODUCTION

During the 5 years 1962 through 1966, some of us at the Bureau of Commercial Fisheries Technological Laboratory at Seattle, Washington, evaluated the quality and condition of Pacific halibut landed at ports in Alaska, British Columbia, and Washington. When the fishing vessels were unloaded, we occasionally noted that the halibut showed an excessive loss of quality and that this loss of quality was more serious among the small halibut than among the large ones. We also noted that these small halibut usually had little or no ice in their pokes (the poke includes the mouth cavity and the visceral cavity), whereas the large halibut ordinarily contained at least some ice. In addition, we noted in the summer that the

Authors: Wayne Tretsven and Harold Barnett, *Research Chemists*, Bureau of Commercial Fisheries Technological Laboratory, 2725 Montlake Boulevard East, Seattle, Washington 98102.
Published February 1970.

vessels, which usually brought in halibut of good quality, occasionally landed halibut of poor quality because of inadequate icing. One other thing we noted was that the methods of handling the halibut greatly influenced their quality.

These observations prompted us to study factors involved in the handling and icing of halibut. The purposes of this article are to report our findings and to give recommendations that will increase the effectiveness of the handling and icing of halibut and will thereby help to ensure that the consumer will have halibut of uniformly high quality.

Because the quality of halibut is so closely related to the method of icing used, you can tell much about the quality of halibut simply by observing how well they have been iced. In the following discussion, we consider first the factors that affect the handling and icing of halibut and then the factors that indicate the quality history of halibut.

I. FACTORS THAT AFFECT THE HANDLING AND ICING OF HALIBUT

Factors that affect the icing of halibut include (A) the size of the poke and the density of the ice used and (B) other factors -- such as: (1) the temperatures of the halibut, of the ice, and of the surrounding and (2) mechanical refrigeration.

A. SIZE OF POKE AND DENSITY OF ICE

Halibut are a relatively large, thick-bodied fish having good storage qualities; however, when stored in ice, undesirable discolorations of the white skin (Figure 1) and indentations

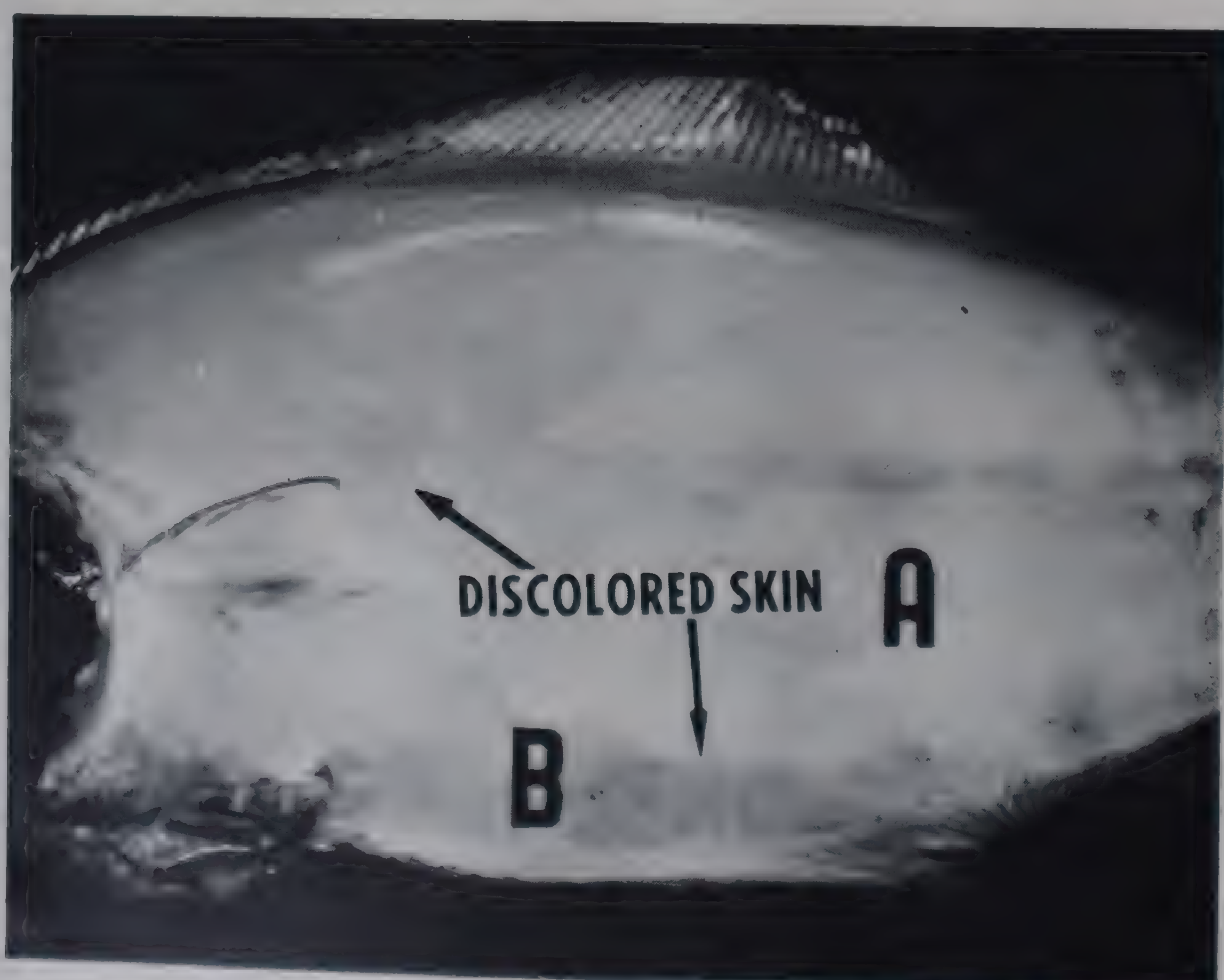


Figure 1.—Fresh halibut showing: (A) a white skin area that had been in direct contact with other halibut and (B) a discolored "yellowing" area due to aerobic growth of *Pseudomonas fluorescens*.

(Figure 2) due to particles of ice may occur. The discoloration is a "yellowing" or "greening" and is due to the growth of *Pseudomonas fluorescens*, a motile bacterium that grows on the slime at low temperatures in the presence of free oxygen.[1] The discoloration is on areas of the skin where oxygen is available, as in the proximity of pieces of ice or open spaces, and it doesn't occur where oxygen isn't available.

Special techniques have been developed to overcome these undesirable conditions. Emphasis has been directed toward filling the poke with crushed or flake ice and toward limiting the amount of ice distributed between and around the halibut to only that which will melt and provide adequate chilling without any pieces of ice remaining to cause discoloration or indentation of the skin. Instead of icing halibut on shelves where they would be exposed to oxygen, the halibut are now iced and packed tightly in pens to exclude the presence of oxygen. As in the icing of other fishes, however, a layer of ice is used to keep the halibut away from the sides of the hold and away from the bottom of the hold, and ice is applied to the top of the load.

Except for the top layers of halibut, the iced halibut are usually placed on their side with the dark side down and the white side up. Small hemorrhages and bruises that objectionably affect the appearance of the white side tend to disappear when the halibut are iced in this position.

For economic reasons -- primarily, the time and labor required -- some fishermen do not attempt to ice the pokes of the small halibut as well as they do those of the more valuable large halibut. Unfortunately, however, when small halibut spoil, they contribute to an increased rate of spoilage of the entire lot.

[1] F. C. Harrison. 1929. The discoloration of halibut. Nat. Res. Counc. Can, pp. 214-239.

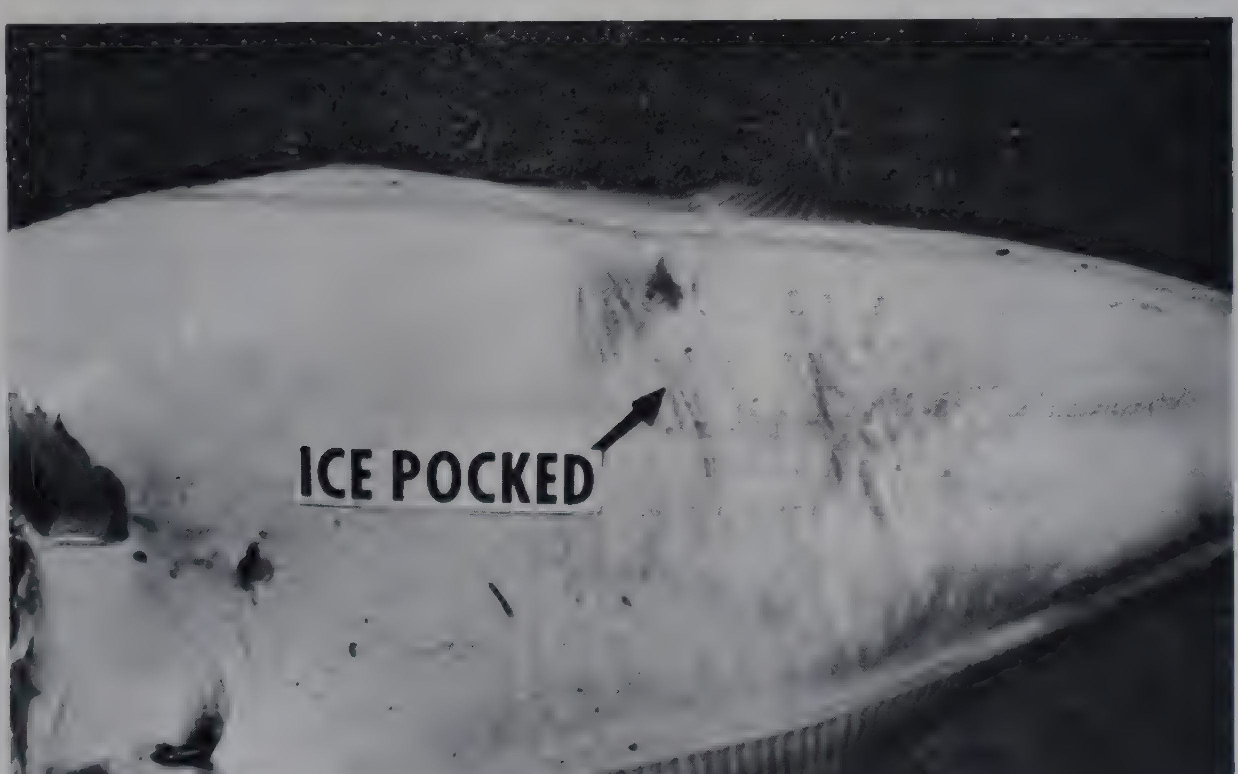


Figure 2.–Fresh halibut having "ice pocks"--that is, indentations caused by particles of ice between iced fish.

Because we found that inadequate icing was associated primarily with the smaller halibut, we studied the icing of halibut of various sizes to find why the smaller ones were sometimes poorly iced.

We assumed that the size of the poke is proportional to the size of the halibut and, hence, that the amount of ice that can be packed in the poke is also proportional to the size of the halibut. Bell (1966),[2] in discussing poke size, commented on factors that affect the ratio of weight of viscera to the weight of halibut, and he stated: "The observed individual variation has been from a minimum of 6 percent to about 27 percent maximum." His data indicate that the poke represents a slightly greater portion in large halibut than in small halibut.

We found variations in both the size of the poke and the shape of the poke among halibut of similar weight in our sampling of commercial halibut. Halibut of various sizes caught in July near Goose Island, which is about 75 miles north of Vancouver Island, were quite plump and had relatively small pokes that represented about 16 percent by volume of the whole halibut. On the other hand, those caught in November in the Bering Sea were big-bellied halibut whose pokes represented 22 percent of their volume. In general, we found that the size of the poke is proportional to the size of the halibut and that the poke represents about 18 percent of the volume of the whole halibut.

When the poke is iced, the sides of the head and body walls bulge, thereby permitting more ice to be added to the poke. In spite of this bulging, the amount of ice that can be packed into the poke is, of course, limited by the size and shape of the poke. With smaller halibut, bulging of the body wall is more limited than it is with larger halibut, and proportionately less ice can therefore be packed into the pokes of small halibut. On a weight basis, the ice equalled about 17 percent of the weight of the large halibut and only about 6 percent of the weight of the small halibut.

[2] H. F. Bell, Director of Investigations, International Halibut Commission, Seattle, Washington, private communication, March 30, 1966.

The bulk density of the commercial crushed ice and flake ice obtained at various times and locations during this study varied considerably. It ranged from 28 pounds to 39 pounds per cubic foot. As the amount (weight) of ice in the poke is affected by the density of the ice, the use of low-density ice may contribute to inadequate icing. The amount of low-density ice that can be packed into the poke of a small halibut may not be enough to chill the halibut adequately.

B. OTHER IMPORTANT FACTORS

We consider first such handling factors as stunning, bleeding, cleaning, removing body heat, and draining away melt water and then consider mechanical refrigeration.

1. Handling Factors

During our study of temperatures aboard commercial halibut vessels, we simultaneously observed the handling practices aboard the vessels. On some vessels, the method of handling caused the halibut to lose quality.

a. Halibut that had not been stunned often bruised themselves when struggling on deck. Dressed halibut were frequently bruised (Figures 3 and 4) by being dropped into the hold.

b. Halibut were not always bled adequately. (Bleeding results in halibut of a lighter, more desirable, color.)

c. Halibut were not always cleaned adequately.

d. Halibut were sometimes purposely left on deck for as long as several hours, because the fishermen believed that the body heat should be dissipated before the halibut are chilled with ice in the hold.

e. Incoming iced halibut sometimes lay in melt water in the pens, because the water had accumulated faster than it had drained out.

After finding that the internal temperatures were higher in small halibut lying on deck than

Figure 3.–The knife held by the fletcher indicates where an internal bruise occurs. The bruise was caused by the halibut being dropped from the hatch onto ice.

Figure 4.—An internal bruise caused by dropping the halibut onto ice.

in larger ones, we studied temperature in greater detail.

The internal temperatures of halibut caught on adjacent hooks on the same line or on nearly adjacent hooks were determined at the following times: (a) immediately after the halibut were landed on the deck; (b) after they lay on the deck 6 hours; (c) after they were iced 24 hours; and (d) after they were iced 48 hours.

Table 1 shows that immediately after the halibut were landed on the deck, the internal temperature of the small halibut was 4° F. higher than that of the large halibut. This difference in temperature applied to halibut brought to the surface by a gurdy operating at full speed -- that is, at 146 feet per minute. Lengthy delays in pulling in the line caused the temperature of the halibut to approach more nearly that of the surface water. This finding applied both to large halibut and to small ones.

Changes in temperature occur more rapidly, however, in the smaller halibut. This fact is reflected in the more rapid rate at which they deteriorate in quality, and it emphasizes the adverse effect of holding them at a relatively high temperature for even a short time.

Allowing the temperature of halibut to rise by leaving them on deck should therefore be avoided. Not only does the quality of the halibut deteriorate rapidly when their temperature rises, but both more ice and more time are then required to chill the halibut adequately. Thus, from the standpoint of both quality and economy, the temperature of halibut should be kept from rising.

Aged ice is sought by halibut fishermen because they believe that it preserves the halibut better than freshly made ice does. Aged ice is usually kept in cold storage, where it is gradually cooled considerably below its melting point. Aged ice is usually available at the start of the halibut season but is seldom available during the summer, when spoilage is more of a problem. Undoubtedly, the favorable reputation of aged ice is due to its lower temperature making it easier to handle and last longer.

Table 1.—Internal temperatures of halibut aboard a fishing vessel

Time of temperature measurement	Internal temperature of halibut weighing:			
	18-22 lbs.	27-32 lbs.	38-44 lbs.	76-84 lbs.
	°F.	°F.	°F.	°F.
Immediately after the halibut were landed on the deck	48	47	47	44
After the halibut had lain 6 hours on deck . . .	67	66	64	57
After the halibut had been iced for 24 hours . .	34	34	35	36
After the halibut had been iced for 48 hours . .	33	33	33	34

Note 1: The vessel was fishing near the Queen Charlotte Islands, August 1966. The temperature of the water was 43° F. at the bottom and 54° F. at the surface. The ambient air temperature was 70° F.

Note 2: The internal temperature of the halibut was determined by inserting a thermometer into the center of the body, with the bulb of the thermometer at the thickest part of the body.

Use of colder ices in sufficient quantities can chill halibut to temperatures below 32° F., and holding at the lower temperatures can result in retaining quality for a longer time. Most research workers advocate the use of ice at its melting point because it is at this temperature that it absorbs the most heat. In addition, water from the melting ice is probably useful in washing slime and bacteria from the fish.

Storage at temperatures lower than that of melting ice, however, permits fresh halibut to be stored for longer times with less loss of quality due to bacterial action and to loss of fluid from the flesh than when the halibut are stored in melting ice. With mechanical refrigeration, fresh halibut can be maintained at temperatures of 29° F. to 32° F.

If mechanical refrigeration is used, care must be taken not to lower the temperature of the halibut below 29° F., its initial freezing point. Otherwise, problems may be encountered in unloading the frozen halibut.

Most fishermen, in attempting to control the temperature of the halibut, dress them and put the dressed halibut into the hold as soon as possible. As a number of halibut are accumulated in the hold before they are iced, some of the halibut undergo a slow and limited prechilling before being iced. Prechilling by immersing the dressed halibut in slush ice, refrigerated sea water, or refrigerated brine is recommended because the chilling is not only

rapid but the prechilled halibut can be stowed with less ice, thereby permitting the stowage of more halibut in the same space.

Considerable ice (refrigeration) is required to dissipate the heat that enters the hold. Insulating the bulkheads, the sides of the hold, and top of the hold; flooding the deck with sea water; and placing barriers such as curtains at the opening of the hatch are means of reducing the infiltration of heat to keep the temperature from rising unduly.

2. Mechanical Refrigeration

Mechanical refrigeration is used in most halibut vessels primarily to reduce the amount of ice required and thereby permit larger payloads. In addition, colder temperatures can be attained, which can result in halibut of better quality and of increased keeping time. Mechanical refrigeration is used effectively by (a) prechilling the hold before ice is taken aboard, (b) chilling and keeping the ice at a lower temperature, and (c) keeping the iced halibut at 29° F.

II. FACTORS THAT INDICATE THE HISTORY OF ICING

Because fresh-water ice melts and refreezes at 32° F., its condition within iced halibut indicates how well the halibut have been chilled and stored. Loose and dry particles of ice with little or no evidence of melting and of freezing indicate that the halibut were maintained at a temperature below 32° F. and that the ice used has melted little or not at all, owing to its initial low temperature or to the prechilling of the halibut, or to both. Dry clumps of ice indicate that the ice melted partially, probably during the chilling of the halibut, followed by freezing of the ice due to the lower storage temperatures attained by mechanical refrigeration. Clumps composed of large aggregates of ice indicate that more ice has melted and resolidified than do clumps composed of many small particles of ice. Ice in a melting condition (Figure 5) indicates temperatures of 32° F. or higher, and if the ice is dirty, is discolored, and has a foul odor, it indicates that the quality of the halibut has probably deteriorated. When little or no ice is present, the halibut have been inadequately iced or have been held for too long a time. Under these circumstances, the halibut could have spoiled.

RECOMMENDATIONS FOR HANDLING AND ICING FRESH HALIBUT

1. Stun and bleed the halibut as they come aboard the vessel.
2. Immediately after bleeding them, dress and clean them inside and outside.
3. Keep the temperature of the halibut from increasing.
4. Immediately after cleaning each halibut, slide it down a chute into the hold; do not bruise it by dropping it.
5. Prechill the halibut.
6. Ice the pokes of all halibut--small halibut as well as large ones.
7. Lay iced halibut with the dark side down and the white side up.
8. Because the pokes of small halibut are often iced inadequately, use additional ice around the small halibut. (Note: To risk discoloration of the skin resulting from the use of the ice around the halibut, which permits the growth of aerobic bacteria, is better than to risk spoilage of the flesh.)
9. Use ice of high density and low temperature.
10. Use mechanical refrigeration to lower the temperature of the hold before obtaining ice; maintain the iced halibut close to 29° F., but <u>do not allow them to freeze.</u>
11. Use thermometers placed throughout the hold to measure the temperature.

Figure 5.–Halibut in dirty, discolored melting ice.

12. Use more ice in warm weather than in cool weather.

13. Reduce the amount of heat entering the hold by using effective insulation, by providing curtains as heat barriers about the chute leading from the hatch opening to the ice, and by flooding the deck with sea water.

14. Provide drainage facilities throughout the pens and the holds to prevent blood, slime, or melt water from accumulating and from thereby contaminating the halibut.

MS. #1974
GPO 996-645

PHYCOCOLLOIDS

by

Norman W. Durrant and F. Bruce Sanford

ABSTRACT

Although phycocolloids--gelatinous materials produced from seaweeds--are economically important, they are not widely known materials. This paper discusses the three principal phycolloids manufactured in this country--namely, agar-agar, algin, and carrageenan --and outlines the ways they are produced and the ways they are used. At the manufacturer's level, these three phycocolloids are worth about 15 million dollars a year to the United States.

CONTENTS

Authors: Norman W. Durrant, *Chemist*, Bureau of Commercial Fisheries Division of Food Science, U.S. Department of the Interior, Washington, D.C. 20240, and F. Bruce Sanford, *Senior Scientific Editor*, Bureau of Commercial Fisheries Division of Publications, Building 67, U.S. Naval Air Station, Seattle, Washington 98115.
Published February 1970.

INTRODUCTION

Algae have been classified in several ways. One common way is to divide them into four major classes on the basis of their color--*Chlorophyceae* (green algae), *Cyanophyceae* (blue-green algae), *Phaeophyceae* (brown algae), and the *Rhodophyceae* (red algae). The green and blue-green algae usually grow in fresh water, whereas the brown and red algae are found almost exclusively in marine habitats. These latter are the algae usually referred to as seaweeds. Of the four classes, the brown and the red marine algae provide the principal products of commerce.

The main commercial value of seaweeds lies in the products derived from them by chemical treatment. In the past, these products have included a wide variety of materials, such as iodine, acetone, and various minerals (Sanford, 1958). Owing to competition from other more economically practical sources, however, these materials are no longer derived from seaweed in this country. The major seaweed products manufactured in the United States today are those that have the ability to form gels and colloidal suspensions--that is, the phycocolloids (Idson, 1956; Whistler and BeMiller, 1959). The term "phycocolloid" comes from two Greek words, *phykos*, meaning seaweed, and *kolla*, meaning glue. The last part of the term derives from one of its physical characteristics.

Although the phycocolloids are strategically and economically important, they are not widely known materials. The purpose of this article, therefore, is to discuss these important marine products derived from our seaweed industry.

For the purpose of this article, phycocolloids are divided into two main groups: those of minor economic importance and those of major economic importance.

I. PHYCOCOLLOIDS OF MINOR ECONOMIC IMPORTANCE

The phycocolloids of minor importance include laminaran and fucoidan from brown algae as well as funoran from red algae (Whistler and BeMiller, 1959). A far larger number of these minor phycocolloids could be manufactured if an economic use could be found for them.

Laminaran, which, as the name would lead one to suspect, comes from *Laminaria*, a genus of kelps. Laminaran, a polysaccharide with starchlike properties, can be used in the production of a soluble surgical dusting powder. Sodium laminaran sulfate may find use as a blood anticoagulant; hydroxyethyl laminaran, as a plasma substitute.

Funoran is a gluey material obtained principally from funori, the dried matter prepared by the Japanese from *Gloiopeltis*. Funori has long been used in the Orient for sizing textiles --it is the pasty substance applied to cloth as a glaze or filler.

Several other derivatives have been isolated from seaweed, but they are primarily laboratory curiosities that have little commercial importance at present.

II. PHYCOCOLLOIDS OF MAJOR ECONOMIC IMPORTANCE

The principal colloidal products made from seaweed are agar-agar, algin, and carrageenan (Figure 1). These products are used in foods, pharmaceuticals, and industrial materials.

To place the colloidal products industry in economic perspective, we first look into the economic value of the major phycocolloids; then we consider each of the phycocolloids individually.

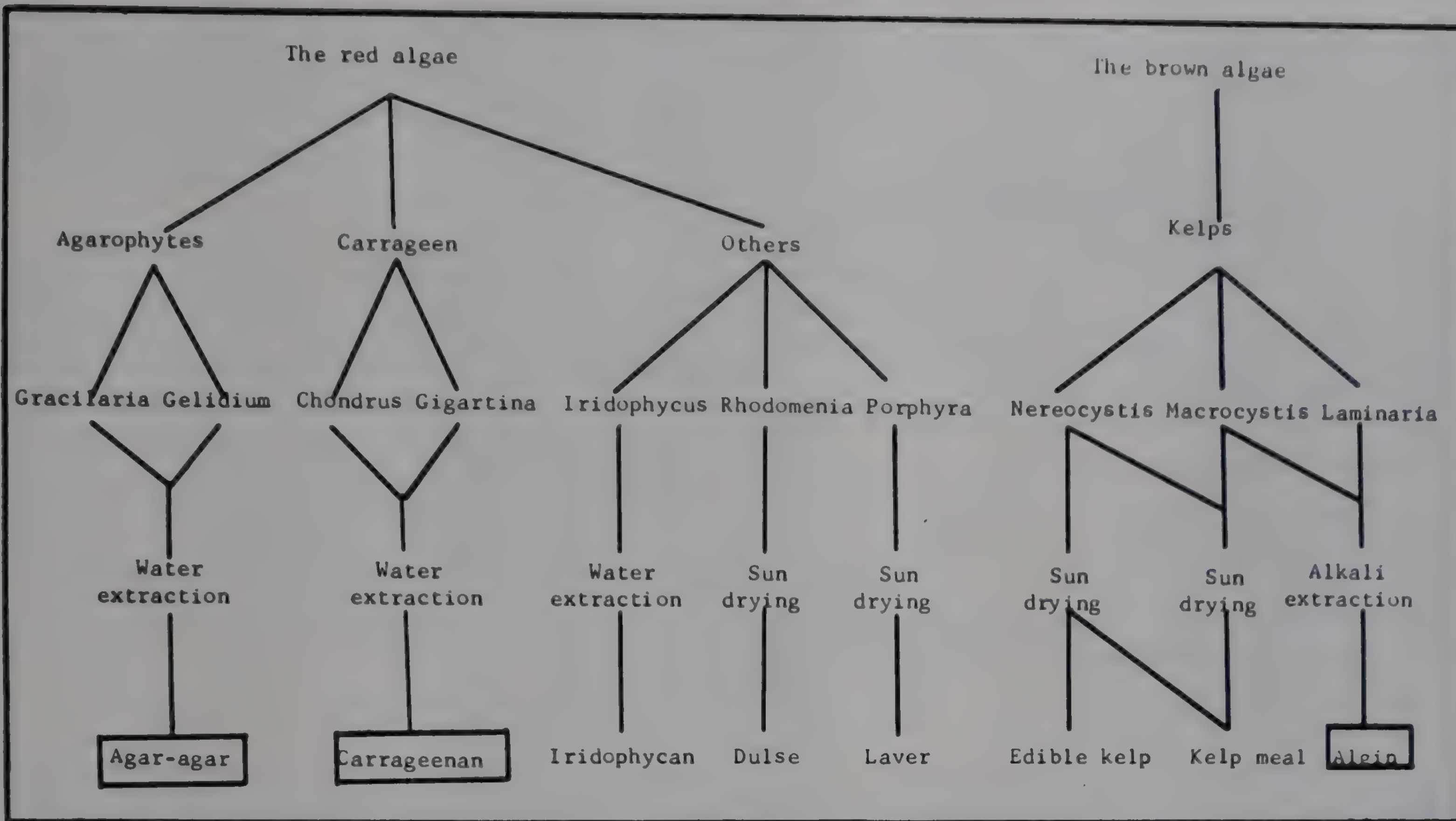


Figure 1.–The commercially important seaweeds of the United States and the primary products (including food, etc.) derived from them.

A. ECONOMIC VALUE OF THE MAJOR COLLOIDS

U.S. seaweed processors produce nearly 15 million dollars worth of agar-agar, algin, and carrageenan each year. These seaweed colloids compete with colloids derived from other sources--for example, gelatin, methyl and carboxymethyl celluloses, starches, pectin, and various industrial gums. Some of the newer synthetics, such as polyvinyl-pyrrolidone, polyoxyethylenes, and polyacrylamides, also compete with phycocolloid products in the United States (Idson, 1956; Whistler and BeMiller, 1959).

When prices of seaweed colloids are compared with those of other colloidal materials, seaweed products appear to be at a disadvantage, especially in the food, pharmaceutical, and cosmetic fields. Algin and carrageenan cost about 1 to 2 dollars a pound; agar-agar, about 4 dollars a pound. Prices per pound for competitive material are roughly 1 dollar for gelatin, 75 cents for cellulose ethers, 50 cents to 1 dollar for various tree gums (arabic, karaya, and tragacanth), and 15 to 20 cents for starches. When used, however, seaweed colloids often prove more economical than do lower priced competitive materials for two reasons. First, small amounts go a long way. Second, they often have special properties that the competitive products do not have.

There are many examples of special properties of seaweed colloids. Carrageenan and algin products have invaded the market and are now useful stabilizers for ice creams and chocolate milk. Agar-agar now is unchallenged as a gelling agent in bacteriological media. Other important uses for seaweed extractives will be discussed in detail later.

Certain nonseaweed materials occupy, through traditional usage, almost impregnable positions in food fields. Pectin, an extract of fruit peel, is traditionally used in making household jelly. Gelatin, which is obtained from animal matter, is the gelling agent primarily used in making most clear desserts and marshmallows. Carboxymethyl cellulose and methyl cellulose, both of which are derived from cellulose fibers, are widely used in dietetic bulk foods and laxatives. Starches from potatoes and cereals lead in the pudding

market, and casein-phosphate (from milk) leads in the instant-pudding field (Idson, 1956).

B. MAJOR PHYCOCOLLOIDS CONSIDERED INDIVIDUALLY

Having considered briefly the economic value of the three major phycocolloids--agar-agar, algin, and carrageenan--we now consider each of them individually, in detail.

1. Agar-Agar

We consider first the production of agar-agar and then its use.

a. Production.—Because harvesting is one of the critical determinants in the economics of seaweed colloids, we look first at the habitat of the seaweeds from which agar-agar is derived and the methods by which they are harvested. We then shall look into the manufacturing process.

(1) Harvesting. — Agar is obtained from red-purple seaweeds belonging to the botanical class *Rhodophyceae*, or red algae. They grow in nearly all the oceans but are gathered mainly off the coasts of South America, North America (primarily Mexico), and Africa. Unfortunately, only a few of the class contain agar. Along the West Coast of North America, the most prevalent of the seaweeds containing agar is *Gelidium cartilagineum.*

Usually, agar-bearing seaweeds (Figure 2)

Figure 2.–On the left, a bed of *Gelidium cartilagineum*, one of the principal seaweed species used in the manufacture of agar-agar.

grow on the ocean floor at depths rarely exceeding about 150 feet. In the turbulent waters where they ordinarily grow, they attach themselves to rough rocks.

Primitive methods are still used to harvest the seaweeds for making agar. Some are pulled into rowboats with rakes or gathered by waders at low tide. Others are collected by divers; SCUBA diving is the most common method (Figure 3). In Mexican waters, from whence most of the seaweed for U.S. agar production comes, the divers wear head-to-toe pressure suits and helmets (Figure 4).

The divers frequently live and work the entire season, which comprises all but two of the winter months, in isolated camps on offshore islands. From the base camp, the diver and his helpers ride to the seaweed beds in a pango, or diving boat. By using a diving helmet, he can stay down from 1 to 4 hours. About 1,500 pounds of wet weed represents a good day's work (Figures 5 and 6). Experienced divers claim that octopi, moray eels, barracuda, and sharks are not troublesome; the real dangers, they say, are the sharp rocks, swells, and bottom currents that can cut or snap an air hose or a lifeline.

After being brought ashore, the seaweed (Figure 7) is sun-dried, baled, and shipped to the processing plant.

(2) Manufacturing. — Once the baled seaweed has arrived at the processing plant, the many steps in the extraction and purification of agar begin (American Agar and Chemical Company, San Diego). Rigid chemical, physical, and bacteriological control is maintained (Figure 8) for several reasons. The raw material varies from batch to batch, yet the final product must be uniform. Because agar is chemically sensitive, it is subject to subtle variations and reactions; yet the requirements of the U.S. Pharmacopeia--as well as those of the Armed Forces, the industries, and the laboratories, where the agar will be used--must be met or exceeded. Hence, a host of the sea's minerals and other substances that constitute impurities must be removed.

Figure 3.–Divers preparing for underwater harvesting of *Gelidium cartilagineum.*

Figure 4.—Diver in pressure suit.

Figure 5.—Diver with an armful of *Gelidium cartilagineum*, illustrating the laborious method of harvesting.

Figure 6.—A netful of *Gelidium cartilagineum* from the ocean floor being dumped in the boat.

Figure 7.—*Gelidium cartilagineum* being spread on the beach to dry.

Figure 8.—Examination of gel sample as one step in the rigid control of quality.

The impurities are removed in eight steps:

1. The seaweed is thoroughly washed (Figure 9) to remove such palpable matter as foreign gums, sea salts, and calcareous incrustations and shells. This preliminary processing may take up to 2 days.
2. The seaweed is placed in large autoclaves or pressure cookers (Figure 10) and cooked with water until the agar-containing matter is separated from the fiber.
3. When the extraction is complete, the liquor (the solution of agar in water and the soluble impurities) is poured into sedimentation tanks (Figure 11). Here more of the impurities are precipitated and then are removed by filtration.
4. The remaining liquor is pumped into long sterilized trays where it congeals into sheets of firm, dark-colored, raw agar gel.
5. The gel is frozen and held at a subfreezing temperature for several days (Figure 12). Because the agar itself is insoluble in cold water, certain of the impurities will go into the ice and leave the agar behind. The ice is later melted, and the impurities are washed away.
6. The relatively pure agar is washed again, bleached, sterilized, treated (Figure 13) for removal of the small amount of remaining impurities, and washed yet again.
7. All the free water is removed from the agar by suction (Figure 14), leaving an

Figure 9.—Seaweed being washed and chemically treated to remove various gums and minerals.

Figure 10.—Autoclaves for cooking the seaweed to separate the agar-containing matter from the fiber.

Figure 11.—Sedimentation tanks for the removal of impurities from the agar.

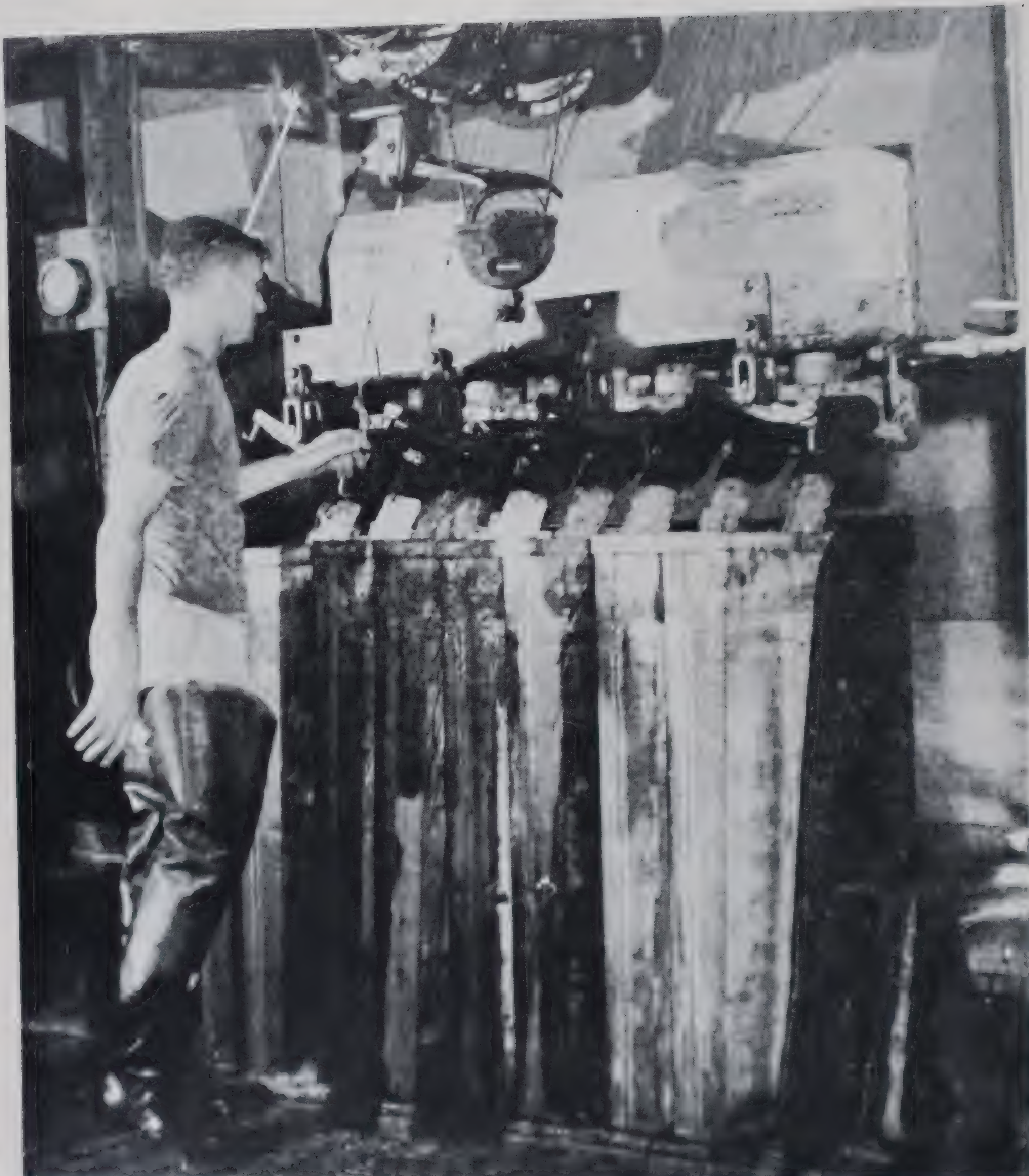


Figure 12.–Gel being frozen--an important step for removing water-soluble impurities.

Figure 13.—Additional washing for removing impurities.

Figure 14.–Removal of water from agar by suction.

odorless, tasteless substance that is practically white.

8. The flakes are literally thrown from heated metal tanks into long fingers or socks of white nylon through which hot air at 250° F. passes continually. The purified agar flakes are now ready for packaging (Figure 15) and marketing.

a. Use.—Because the uses of agar are inextricably bound to its attributes and qualities, we look at the properties that determine its use before we look at the uses themselves.

(1) Properties. — Agar is now known to consist of two fractions, agarose (Figure 16), a nonionic polysaccharide, and agaropectin, an anionic polysaccharide. Agarose is a polymer consisting of alternating 1,3-linked β-D-galactopyranose and 1,4-linked 3,6-anhydro-α-L-galactopyranose units. Agaropectin is more variable in composition, but basically has the agarose structure with ester sulfate groups on some of the sugar units. The anionic nature of agar is due to the sulfate-containing agaropectin component. Calcium, sodium, and magnesium are the principal cations present as counterions in native agar (Guiseley, 1968). Figure 16 shows part of the molecule generally considered to incorporate the gelling function of agar.

The properties of an agar are governed both by the raw material from which it is made and by the care used in making it. Usually, the better agars--that is, those that are the

Figure 15.–Agar being packaged.

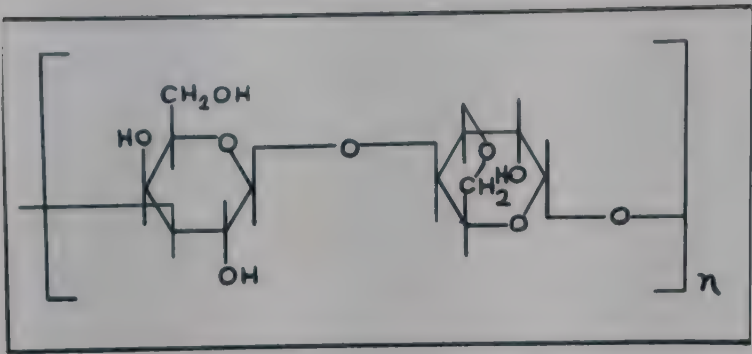


Figure 16.–Gelling component in agar molecule.

most carefully prepared--have the best color, the greatest freedom from extraneous materials, and the strongest gelling capability attainable from the raw material used. The most common variations in agar are in sol viscosity, gelling temperature, gelling strength, degree of syneresis, and gel clarity.

A relatively high temperature (95° to 100° C.) is required for agar to dissolve. The resulting sol has a low viscosity, which changes very slowly with changes in temperature. The transition from sol to gel, however, is fairly abrupt; it starts in the temperature range between 38° and 42° C. and is relatively unaffected by hydrocolloid concentration or other solutes. The gels that can be formed at concentrations of as low as 0.5 percent (the usual concentration is in the range of 1 to 2 percent) are "short"--that is, although they do not flow readily and tend to cut off quickly when poured, they are not stringy--and are thermally reversible. The transparency of the gels is moderately good, but variable.

(2) Primary uses. — The uses of agar are manifold (American Agar and Chemical Company, San Diego; Guiseley, 1968; Tressler and Lemon, 1951; Whistler and BeMiller, 1959), but its most important use is in bacteriological and fungal culture work. It is used in practically all bacteriological studies (Figure 17) of foods, water, drugs, and diseases. Antibiotics and vaccines are produced with the aid of agar.

Agar is unrivaled as a solidifying agent for culture media. Its outstanding properties are: (1) a firm, rubbery surface that is not easily ruptured when organisms are streaked across it by a needle; (2) the ability to remain liquid when cooled to 40° C., so that organisms may be thoroughly mixed with it at a temperature (usually 45° C.) that does not harm them; and (3) reversibility, which enables the agar to be alternately warmed into a sol or cooled

Figure 17.–Microbiologist counting colonies of microbes growing on agar used as a solidifying agent for culture media.

Figure 18.–Use of an agar compound in dental laboratories as an impression material for teeth.

into a gel. Even a dilute solution added to a nutrient material causes the material to set to a firm gel on which bacteria or fungi can grow. The gel will remain firm at 37° C., which is the temperature commonly used for incubating bacterial and fungal cultures. Another value of agar as a bacterial culture is its resistance to liquification. Bacteriological agar remains liquid when cooled to about 40° C., hence most organisms can be thoroughly distributed within it at a temperature that will not harm them. Many bacteria convert solid media such as gelatin into a liquid solution. Although some bacteria are capable of liquefying agar gel, there are relatively few of them.

In addition to its use as a culture for microorganisms, agar is used for food (both "as is" and as a medicine), in industrial processing operations, as a constituent of medical pills and capsules, and in pharmaceutical and cosmetic creams and jellies. In a number of countries, the transport of preserved cooked fish is aided by agar gel--imbedding the fish in the gel protects them from breaking up. It also prevents the constituents of certain fish, such as herring, from blackening the contents of the can.

It is used as a glue, for making silk and paper transparent, as a substitute for such products as gelatin and isinglass, for sizing silks and paper, for dying fabrics, in adhesives, in fish and potato bouillon, for clarifying liquids, for making beer wort, and as a lubricant in wire drawing.

Its other uses are widespread. Agar can be used to make jellies, salad dressing, icings, confections, and aspics that set at room temperature. Some physicians think that it is the only perfect laxative. Orchid culture would be much more difficult without it. People who, for medical or religious reasons, require edible emulsions and gels that are low in sugars, proteins, or animal derivatives find agar admixtures ideal. Agar may be used in dental laboratories in elastic impression material (Figure 18). Plastic surgeons and criminologists use it for making casts and impressions.

Figure 19.–Agar is used in the production of pharmaceuticals and cosmetics.

As a thickener, emulsifier, gelation agent, absorbent, lubricant, and inert carrier, it has many uses, as in the production of pharmaceuticals and wines (Figures 19 and 20).

2. Algin

Following the pattern established in our discussion of agar-agar, we first take up the production of algin and then its use.

a. Production.

(1) Harvesting.—Most of the algin produced in the United States is extracted from the giant kelp *Macrocystis pyrifera*, which is harvested in the offshore waters of the Eastern Pacific. It may also be extracted from *Laminaria digitata* and *Laminaria saccharina*, which grow along the North Atlantic Coast. The giant kelp is found in beds that vary from 50 feet to 1 mile wide and that are often several

miles long (Figure 21). It grows in areas where the water is from 25 to 80 feet deep, the bottom is rocky, and the ocean currents are strong. The rocky bottom, to which it clings, serves as a base for its rootlike structure, called a holdfast. The strong currents supply the constantly renewed nutrients necessary to sustain its growth.

On the Pacific Coast, the giant kelp is harvested with special harvesting vessels equipped with mechanical cutting and loading apparatus (Figure 22). The plants are cut about 3 feet below the surface of the water; cutting the surface growth permits greater penetration of sunlight and thereby promotes denser and more vigorous growth of the younger plants below. New shoots soon reach the surface, permitting the area to be harvested again in about 4 months (Chapman, 1952; Kelco Co., 1968; Newton, 1951; Whistler and BeMiller, 1959).

Figure 20.–Wine is one of the many products in which agar is used during manufacture.

Figure 21.–The giant kelp *(Macrocystis pyrifera)* forms interesting patterns on the surface of the ocean.

Figure 22.–Specially designed sea-going harvesters are used to cut and load kelp.

Since *Laminaria* species are less easily gathered, various handpicking methods are used. Grappling hooks hauled from a power boat at a depth of 12 to 15 feet are the usual harvesting instruments.

(2) Manufacturing. — Two processes primarily are used in the United States for the commercial production (Figure 23) of alginic acid and alginates (Chapman, 1952; Guiseley, 1968; Stoloff, 1954; Tressler and Lemon, 1957). Green's cold process is used on the Pacific Coast to extract the giant kelp, and the Le Gloahec-Herter process was formerly used on the Atlantic Coast to extract the *Laminaria* species. Alginates are no longer produced on the Atlantic Coast of the United States.

(*a*) *Green's process.*—In the cold process (Figure 24), fresh kelp is first leached for several hours with a weak solution of hydrochloric acid to reduce the content of salt. After being chopped and shredded, the leached kelp is digested with a soda-ash solution (40 to 50 pounds per ton of fresh kelp) at a pH of about 10 for about 30 minutes. The digestion process is then repeated. The product is next disintegrated in a hammer mill. Six volumes of water are added, and the mixture is maintained at a pH of 10.6 to 11.0. This mixture is pumped into a tank, where clarifying agents are added, and is allowed to settle. A diatomaceous-earth filter aid is mixed with the supernatant liquor, which is then filtered through a plate-and-frame filter press.

The filtrate, which contains the sodium alginate in solution, is treated with a 10-percent calcium chloride solution to precipitate the alginic acid as the calcium salt. The insoluble calcium alginate rises to the top, and the lower layers of the solution containing soluble salts and soluble organic matter are drained out and discarded. The curdlike calcium alginate is washed with fresh water and is bleached with a dilute solution of sodium hypochlorite.

After being drained, the calcium alginate is converted to alginic acid by treatment with 5-percent hydrochloric acid. The resulting

soluble calcium chloride and the excess acid are drained off through a screen. The remaining solid alginic acid is washed several times with acidulated water to remove any remaining calcium.

The purified alginic acid can be converted into stable sodium alginate or other alginate by treatment with the appropriate carbonate, oxide, or hydroxide.

(*b*) *Le Gloahec-Herter process.* — The Le Gloahec-Herter process (Figure 25) differs from Green's process in a number of ways. Its use of dilute calcium chloride for leaching enables it to remove laminaran and mannitol from the mass without adversely affecting the algin. The seaweed, after being leached, is washed with softened water and then is digested at a temperature of 140° F. in an alkaline medium. The digestion mass is heated and mixed, and the process continues until a homogeneous paste is obtained. The paste is diluted and beaten again, and air is introduced through fine apertures. The use of this latter process results in a product of high viscosity.

b. Use.

(1) Properties.—Algin is the general term designating the hydrophilic or water-loving derivatives of alginic acid (Guiseley, 1968; Kelco Co., 1968; Muncaster and Messina, 1961; Steiner and McNeely, 1951, 1954; Young and McLachlan, 1966). This natural colloid is a polyuronic acid composed mainly of β-(1-4)

Figure 23.–Modern west coast plant for processing kelp into many useful products.

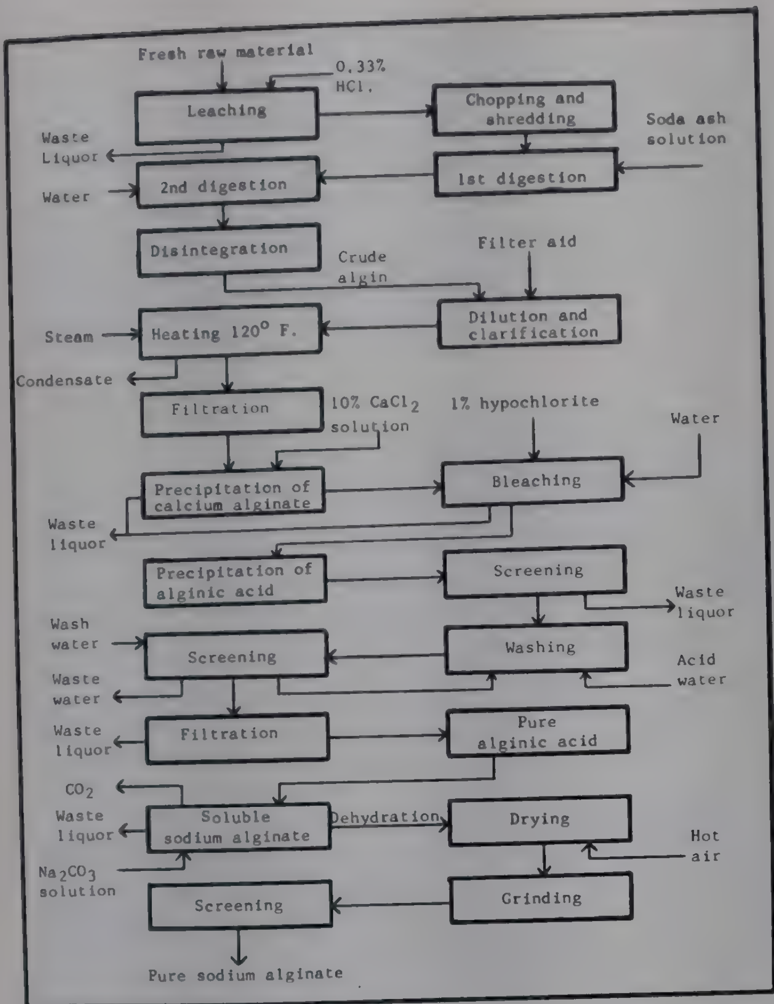


Figure 24.—Flow sheet of Green's cold process.

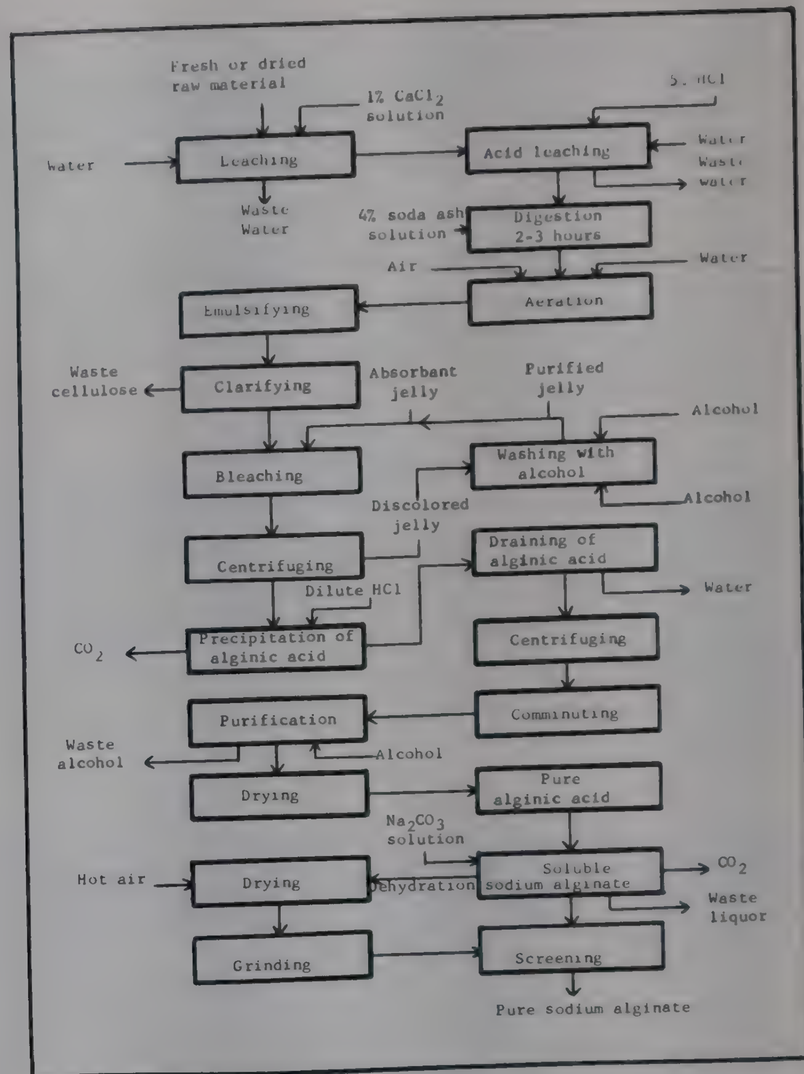


Figure 25.—Flow sheet of Le Gloahec-Herter process.

linked anhydro D-mannuronic acid and anhydro L-guluronic acid. Figure 26 shows the generally accepted structure of alginic acid.

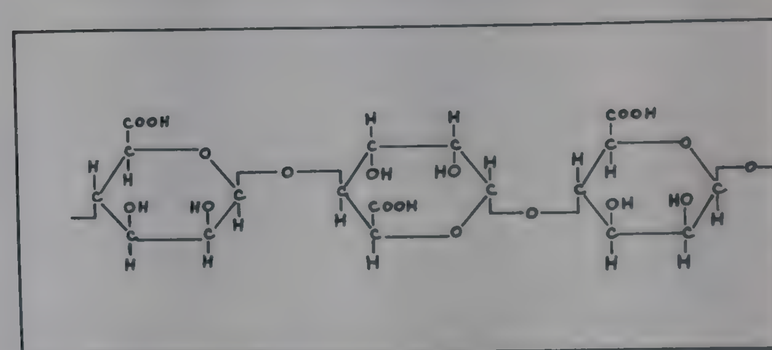


Figure 26.—Structure of alginic acid.

Most alginic acid is capable of absorbing 10 to 20 times its weight in water. When moist, it is readily soluble in dilute alkali, but when dried, it becomes hard and resistant to solvents. Careful control of their process enables manufacturers to supply products that can be used in numerous industrial and food applications.

The technical importance of alginic acid results principally from the properties of its salts. The alkali metal, ammonium salts, and magnesium salt dissolve readily in water and give solutions that do not coagulate or gel on being heated. Solutions of these salts are transparent, colorless, and essentially odorless. They have a wide range of controllable viscosity, which is affected by the addition of calcium ions to solutions of sodium alginate. Preparations may be thickened to creams or converted into jellies, depending on the amount of calcium salt added. Only a small concentration of algin is required. The calcium ions interact with the free carboxyl groups of the algin molecules, linking and intertwining them into a complex network that forms the gel structure.

The addition of about 10 to 25 percent of alkaline phosphates or carbonates, by weight of algin, improves the smoothness and the flow of algin solutions and decreases the viscosity. Such additions form a convenient method of raising the pH. Adding strong alkalis to an algin solution has no immediate effect below

a pH of about 12. At this pH, however, the solution will begin to thicken and form a gel.

Algin solutions can form films that are clear, tough, and flexible and that have good adherent qualities. Not only are these films resistant to greases, oils, fats, waxes, and organic solvents, but they also are compatible with the common hygroscopic plasticizers, such as glycerine and sorbitol. They can be made water resistant either by the addition of urea-formaldehyde-type resins, which make them insoluble on being heated, or by treatment with a solution of an alkaline-earth or heavy metal salt, such as zinc chloride or zirconium oxychloride. An additional method of making water-resistant films is to form a metallic derivative that is soluble in excess ammonium hydroxide. Drying the films drives off ammonia and makes the films insoluble. The metallic derivatives can be formed from the salts of zinc, aluminum, copper, chromium, or iron.

Some additional properties of the algin gel are:

1. No heating or cooling is required in the formation of the gel. Because gelation takes place readily at room temperature, the system is ideal for instant products. Gels can be formed hot or cold with milk or water.

2. The body of the gel can be specifically controlled for formulations ranging from quite light to very firm and heavy. The most effective way of changing the gel body to fit the requirements of a particular formulation, as we noted earlier, is to vary the concentrations of algin and calcium. Although the desired body can sometimes be attained by altering either concentration independently, maintaining a basic ratio of about 1 part calcium salt (by weight) to 3 parts algin (if the calcium salt is di- or tricalcium phosphate) is desirable.

3. Syneresis, or weeping, is greatly retarded because the algin molecule has a strong affinity for water and keeps it tightly bound within the system.

4. The gel has excellent stability toward heat even, for example, under the high temperatures required in the baking industry.

5. The sugar content or pH need not be adjusted for the gel to form. Because sugar and acid can be added only to satisfy flavor requirements, algin gel makes an excellent base for many dietetic products, such as instant milk shakes, puddings, and jellies.

(2) Primary uses.—Algin solutions have been used successfully (Chapman, 1952; Guiseley, 1968; Idson, 1956; Jackson, 1964; Kelco Co., 1968; Muncaster and Messina, 1961; Newton, 1951; Whistler and BeMiller, 1959) to stabilize emulsions and suspensions and to control the formation of crystals, particularly ice crystals. The uses of insoluble calcium alginate and alginic acid are based on their ability to absorb many times their own weight of water. They also can be formed into strong films or fibers, which can either be eaten or be converted back to soluble salts.

One of the most important uses of algin is as a stabilizer to give smooth body and texture to frozen desserts. Such a use is economical, because 1 pound of algin will stabilize about 150 gallons of ice cream.

Important new applications for algin in the food field have been developed during the past few years as a result of the availability of propylene glycol alginate (Figure 27). Although sodium alginate is precipitated as alginic acid at the low pH characteristic of French dressing, propylene glycol alginate is soluble. By acting both as a thickener and as

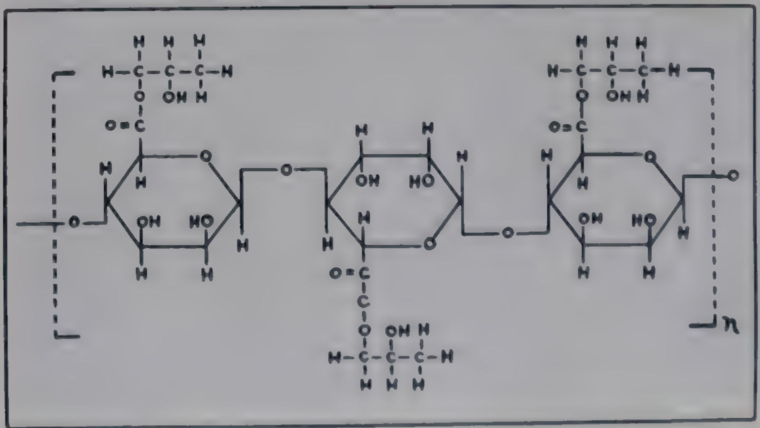


Figure 27.—Propylene glycol alginate.

an emulsifier, propylene glycol alginate prevents the oil in an oil-water emulsion from surfacing during many months of shelf life (Figure 28). It is also useful in acidic solutions, and thus stabilizes various sauces, syrups, and sherbets. It also functions as a very efficient beer-foam stabilizer at a level of about 1.5 pounds per 100 barrels of beer (Figure 29).

Sodium alginate can act as a stabilizing agent in cream substitutes, chocolate milk suspensions, marshmallows, and various drinks. It is a thickening agent for jams and sauces, food jellies, and custard (Figure 30). Various combinations of calcium alginate and water-soluble salts of alginic acid are used in icings and glazes. In the icings on cakes and sweet rolls, for example, the water-holding properties of algin prevent the icings from sticking to the wrappers or from disappearing into the cakes or rolls.

Many people in widely diversified food industries are working on products that are based on the algin gel system. Formulations are now being tested that will undoubtedly lead to many new products.

The algin products--sodium alginate, ammonium alginate, potassium alginate, and calcium

Figure 28.–Propylene glycol alginate is very useful as a stabilizer for salad dressing.

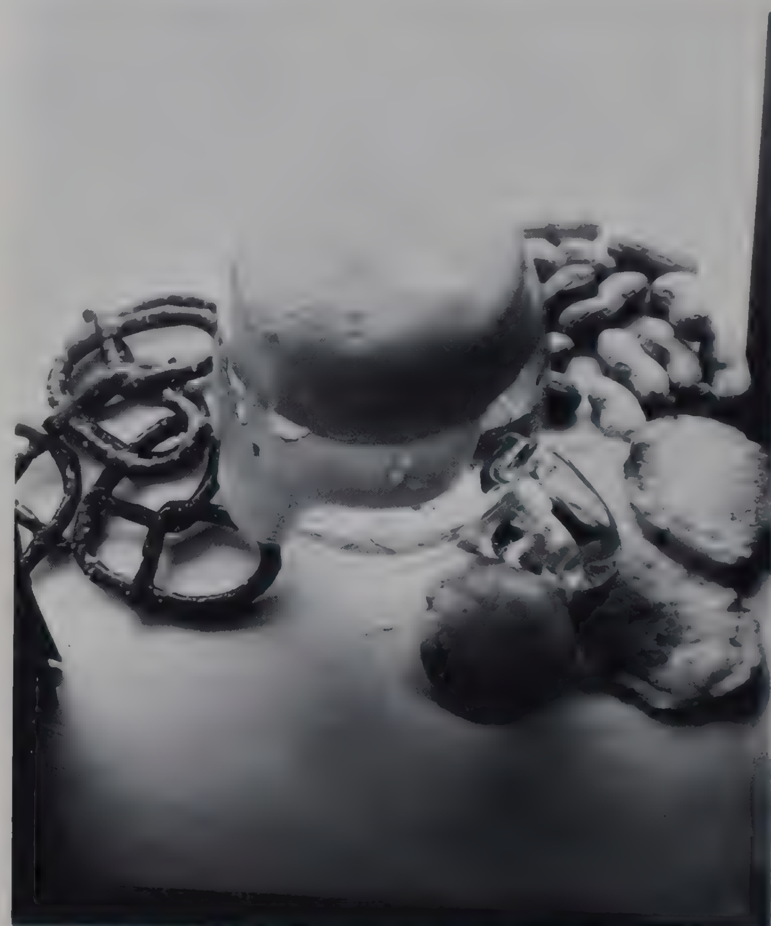


Figure 29.–Propylene glycol alginate delays the collapse of foam in beer.

Figure 30.–Alginates are used as thickening agents in various food items.

alginate--are included in the list of substances judged by the U.S. Food and Drug Administration to be safe within the meaning of the Food Additives Amendment of 1958. Propylene glycol alginate is legally qualified under the Amendment for unrestricted use as a stabilizer, emulsifier, or thickener in all nonstandardized foods and confectionery products. Both sodium alginate and propylene glycol alginate are approved in a number of food standards promulgated by the Food and Drug Administration.

Jelly bases frequently serve as carriers for antiseptics and other drugs that are used for topical application (Figure 31). Algin jellies have emollient qualities that combat chafing, chapping, and ichiness, and that aid in the healing of burns. They yield nongreasy products that have no masking properties. They facilitate both application and removal; they are more stable than oil-based preparations.

Other pharmaceutical uses of algin include those for tablet disintegration and binding (Figure 31), for emulsifying mineral and vegetable oils, and for viscosity control of solutions and syrups; those in surgical jellies and in bulk laxatives; and those in suspending agents, shampoo foam-stabilizers, dental-impression compounds, and bodying agents for weight-control drinks and puddings.

Algin products are widely used in industry for emulsifying, thickening, suspending, stabilizing, gelling, plasticizing, flocculating, binding, and film forming. Plaster and cement products often contain algin products. This group of building materials includes wall-joint cements, texture paints, patching plasters, crack fillers, and acoustical plaster. Some of the advantages of algin-containing products are their improved ability to be worked (for example, their ability to be troweled), their tendency to restrict the penetration of moisture, their capacity to mix with and suspend pigments and clays, and their ability to prevent moisture from separating from the product on standing. These characteristics, because they result in increased working time during application, make the plaster or cement easier to handle and eliminate hairline cracks caused by rapid dehydration.

Figure 31.–The pharmaceutical and cosmetic industries have many uses for alginates.

Other industrial products containing algin include paints (Figure 32), ceramic glazes, welding rods, impression molds, products for

Figure 32.–Many paints and other industrial products contain alginates.

treating municipal and industrial water and boiler water, beet-sugar clarifiers, seed coatings, insecticides, and wax emulsions and polishes.

Sodium alginates are suitable for many textile applications. For example, in the printing of textile fabrics, algin is particularly effective as the thickening agent for dye solutions formulated into printing pastes. Often less than 2 percent of solids supply the necessary thickening to hold the printing characters of the dyes.

Although the largest share of algin used in textiles has been for printing, its use in sizing, finishing, rug backing, synthetic fiber manufacturing, and special new dying techniques is increasing.

Algin has several characteristics that make its products valuable ingredients to the paper and paperboard industry.

1. Being hydrophilic, they are readily soluble in either cold or warm water and are resistant to wax, grease, oils, and most organic solvents. They improve general printability and holdout of glossy ink.

2. They are excellent film formers for the production of continuous or semicontinuous films on the surface of paper or paperboard.

3. They control the penetration of water solutions. When used with other colloids or water-dispersed materials, they hold these products on the surface of fibrous webs.

4. They are compatible with most water-soluble and water-dispersible materials, such as starch, casein, resin and latex emulsions, protein, wax emulsions, gums, and plasticizers.

5. They are nontacky and therefore are ideal for high-speed calendar and sizing operations.

6. They improve gluing operations, because algin-treated board is more rewettable than are most other colloid-treated boards.

The alginate industry in the United States is highly oriented to research. Customer requirements form the basis for a continuous program of research and development of new products to meet industry needs. Researchers develop new formulas and prepare samples that are thoroughly tested, evaluated, and modified in the laboratory. Modern facilities are available for carrying out these research and development programs (Figure 33).

3. Carrageenan

a. Production.

(1) Harvesting.—Carrageenan is extracted primarily from the red seaweeds *Chondrus crispus* and *Gigartina stellata.* However, the name carrageenan also often applies to the extracts from other red seaweeds such as the *Eucheuma* and *Iridea* types, which are also used as sources of carrageenan in the United States. However, Irish moss (*Chondrus crispus*) (Figure 34) is the only native source of carrageenan in this country. It is harvested along the rocky shores of the North Atlantic Coast from New York to Nova Scotia (Chapman, 1952; Guiseley, 1968; Tressler and Lemon, 1951; Whistler and BeMiller, 1959).

North America imported some of its supplies from Europe until 1939, after which the industry for harvesting the plants and preparing the extract expanded in New England and the Maritime Provinces. Canada harvests large quantities of Irish moss and is now a competitor in world markets.

The Irish moss industry of New England represents the oldest seaweed industry in the United States; it dates from 1835. Harvesting began at Scituate, Massachusetts, which was considered to be the mossing center of the United States.

Irish moss grows from just above low-water level down to a depth of about 20 feet and can be gathered from May until about the first of September. Old fashioned methods of harvesting are still used. The mosslike algae are generally harvested by men working from dories with lead-weighted rakes that are 15 to 20 feet long (Figure 35). An experienced man

Figure 33.—Research and development programs for alginates are carried out in modern facilities.

Figure 34.—Irish moss *(Chondrus crispus).*

can gather from 500 to 1,000 pounds per day under good harvesting conditions. In some areas, large amounts of Irish moss may be collected from beaches (Figure 36), where it is washed ashore during storms.

The plants, after being gathered, are either sun dried or dried in a mechanical dryer (Figure 37). Before the development of mechanical dryers, the moss was available as a sun-dried bleached or unbleached (black moss) raw material. Sun-bleached moss was prepared by washing in sea water periodically to prolong the drying process, thus allowing the sun's rays to destroy the pigments in the moss. This process usually required about 2 weeks. Irish moss can also be bleached artificially with sulfur dioxide. Residual sulfur dioxide, which is pale yellow, can be removed by washing the plant with a solution of potassium chloride. The industry has gradually been shifting to a

Figure 35.–Harvesting growing Irish moss (raking).

Figure 36.–Harvesting storm tossed seaweed on Prince Edward Island.

Figure 37.—A mechanical moss dryer.

greater use of unbleached moss in view of improved refining techniques and the installation of oil-fired dryers along the Northeast Coast of New England and the Maritime Provinces. These devices have greatly accelerated the drying operation.

Following the drying process, the moss is machine-baled for shipment to the processing plant (Figure 38) or storage in a seaweed warehouse (Figure 39).

(2) Manufacturing.—At the processing plant (Figures 40 and 41), water and mechanical devices give the moss a preliminary cleaning that serves to remove most of the extraneous substances such as salts, sand, stones, shells, and other undesirable materials. Then the cleaned material is extracted (Guiseley, 1968; Tressler and Lemon, 1951; Whistler and BeMiller, 1959) with hot water to which alkaline reagents such as calcium or sodium hydroxide are added. The extract is pumped into large tanks where it is held for several hours at 90° to 95° C., then, with the addition of a filter aid, the carrageenan solution is clarified by filtration in mechanical filter presses (Figure 42). The clarified extract may be concentrated prior to recovery of the extractive, either by drying on hot rolls or drums or by precipitating (through dehydration) with isopropyl alcohol. Prior to roll or drum drying (Figure 43), it may be necessary to decolorize the extract with charcoal to remove undesirable

Figure 38.—Moving baled moss.

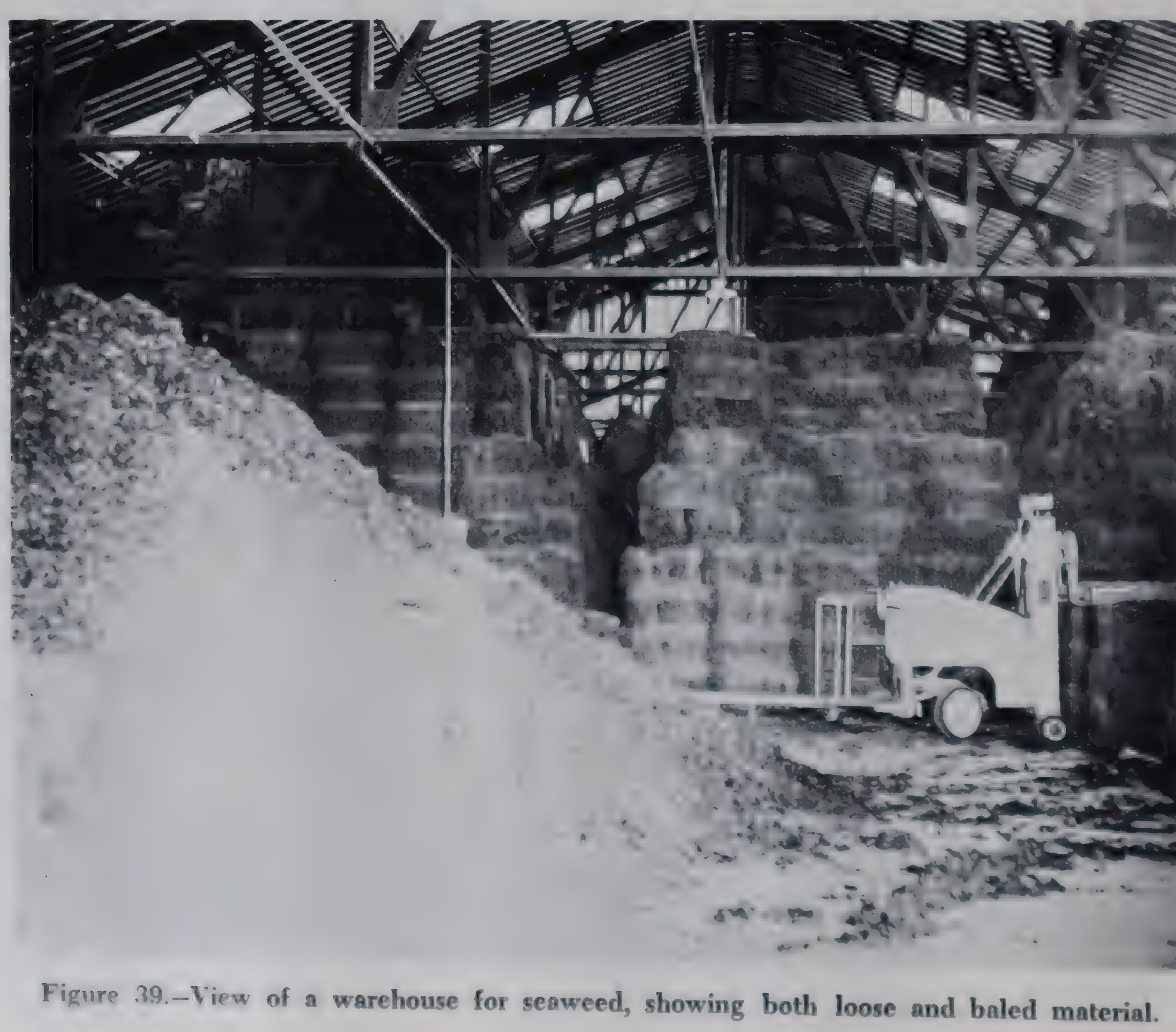


Figure 39.—View of a warehouse for seaweed, showing both loose and baled material.

Figure 40.–A carrageenan producing plant in Maine.

pigments. If the extract is precipitated with isopropyl alcohol, further processing of the precipitate in rotary vacuum dryers is required to remove and recover the excess alcohol. Grinding, blending, and packaging (Figure 44) complete the process. Many refinements, some of which are trade secrets, have been added to the process; the results are a higher yield, a lighter color, more easily controlled viscosity, and better gel strength. A yield of 60 to 80 percent is commonly obtained from clean, thoroughly dried, raw material.

As with agar, the quantity and quality of Irish moss varies with location, weather, and water conditions. Achieving a prime end product, then, depends upon the selection of the raw material, the control of the processing, and the final blending of the production lots.

b. Use.

(1) Properties.—The hydrocolloid carrageenan is a galactosan sulfate having two fractions: kappa and lambda (de Virville and Feldman, 1964; Guiseley, 1968; Marine Colloids, Inc., 1966a, 1966b, 1967; Young and McLachlan, 1966). Kappa carrageenan is a polymer made up largely of alternating 1,3-linked β-D-galactopyranose-4-sulfate and 1,4-linked 3,6-anhydro-α-D-galactopyranose units. A minority of the latter units may be sulfated at C-2 or replaced by α-D-galactopyranose-2,6-disulfate units. Lambda carrageenan has a similar alternating structure, but the sugar units are respectively 1,3-linked, β-D-galactopyranose-2-sulfate and 1,4-linked α-D-galactopyranose-2,6-disulfate. Some of the 1,3-linked

Figure 41.–Aerial view of a carrageenan producing plant in Maine.

units may be unsulfated. Both the kappa and lambda fractions can be divided into two or more distinct subfractions. Figure 45 shows the structural relations.

A third major type of carrageenan, iota carrageenan, occurs mainly in the red seaweed *Eucheuma spinosum*. Iota carrageenan has recently been characterized as similar in structure to kappa carrageenan but with substantially all of the 3,6-anhydride sulfated at C-2.

The lambda fraction is viscous, nongelling, and insensitive to potassium; the kappa fraction is gelling and is sensitive to potassium.

Iota carrageenan gels with potassium and even more so with calcium. The calcium gels are more compliant than those with kappa carrageenan.

A carrageenan sol is a strongly charged polyelectrolyte in which the sulfates are about 60-percent ionized. One sulfate unit accompanies almost every hexose unit. Sols of carrageenan are very viscous at low concentration and form thermally reversible gels on the addition of certain compounds, particularly those of potassium, ammonium, and calcium.

The properties of a carrageenan solution are affected by the nature and relative amounts of other solutes such as sodium, calcium, and potassium contained in the solution. Theoretically, pure sodium kappa carrageenate and pure sodium lambda carrageenate solutions will not form a gel even if they are cooled to the freezing point. However, potassium kappa carrageenate will gel, as will calcium iota carrageenate.

Figure 42.–Setting up a plate and frame filter press.

Figure 43.–Carrageenan coming off a steam-heated roll drier.

Figure 44.–The packaged carrageenan is shipped in fiber drums.

Because agar-agar and carrageenan do not have the same properties, they have different uses. Agar is best suited to uses in which the tendency to form a firm gel is required. Carrageenan is superior for uses that require high viscosity and the concomitant thickening, emulsifying, and suspending properties--although uses dependent upon its gel-forming properties are becoming increasingly important. Most notable are (1) its uses in milk systems wherein a broken gel structure is set up through interactions of (a) carrageenan and milk protein and (b) carrageenan and potassium ions from the milk or added cocoa; and (2) its uses in forming dessert gels. Extremely compliant --that is, gelatinlike--gels may be formed from combinations of various carrageenans or from combinations of carrageenan and locust bean gum. These gels have an advantage over gelatin gels in that they will set above room temperature and will not melt or become soft after being unmolded and placed on the dining table. Another advantage of carrageenan water gels is that they may be packed under high-temperature sterile conditions and stored for many months. Examples of this type product are dessert gels for babies.

Prolonged exposure to high temperature can degrade solutions of carrageenan. The effect is accelerated with decreasing pH and increasing oxidation potential. Below pH 6.0, exposure to high temperatures should be minimized; below pH 3.5, heating usually results in excessive destruction of the hydrocolloid.

(2) Primary uses.—Large quantities of carrageenan are used in nonsettling chocolate milk drinks, ice creams, sherbets, novelty ices, starch-based milk puddings, fruit pies, bakery and fountain specialties, oil emulsions, hand lotions, and toothpastes (Chapman, 1952; Guiseley, 1968; Københavns Pektinfabrik, 1963; Nilson and Wagner, 1959; Whistler and BeMiller, 1959).

When carrageenan is used in ice cream, its primary functions are to prevent ice crystal formation and to stabilize the milk protein system, thereby preventing whey separation.

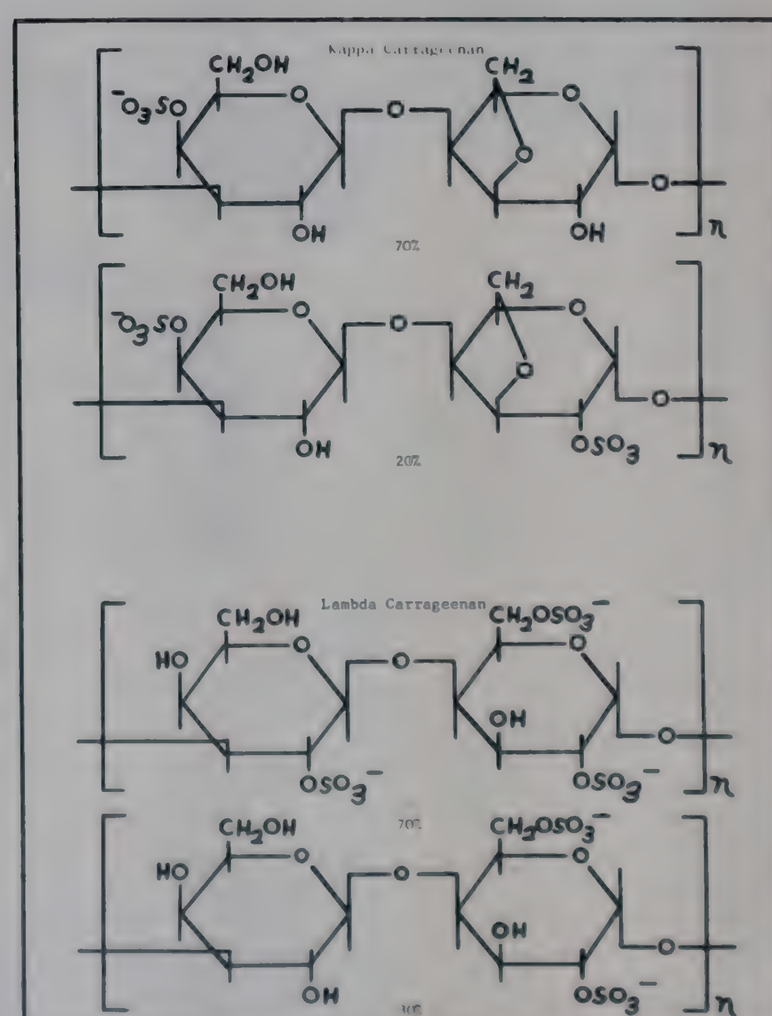


Figure 45.–Kappa and lamda carrageenan.

SUMMARY

Phycocolloids are colloids extracted from seaweeds. This article discusses these marine products, which are of considerable importance economically. They are considered in two groups--those of minor economic importance and those of major economic importance.

Phycocolloids of Minor Economic Importance

The phycocolloids of minor economic importance consist mainly of laminaran, funoran, and fucoidan. A variety of these phycocolloids have been used in the manufacture of surgical powders, textiles, and blood-clotting agents.

Phycocolloids of Major Economic Importance

The phycocolloids of major economic importance are agar-agar, algin, and carrageenan. Collectively, these phycocolloids are worth about 15 million dollars a year to the United States at the manufacturer's level.

Agar-agar.—The major problem in the production of agar-agar is the difficulty in getting the raw material. Agar is obtained primarily from *Gelidium cartilagineum*, a seaweed that is harvested by primitive methods, such as skindiving.

The seaweed is extracted in an autoclave, and the agar is purified in steps, one of which is freezing.

Agar consists of two fractions: agarose, a nonionic polysaccharide, and agaropectin, an anionic polysaccharide.

Agar has many uses as a thickener, emulsifier, gelation agent, absorbent, lubricant, and inert carrier. Its most important use is in the media for bacteriological cultures, for which it has ideal properties.

Algin.—Algin is obtained from the giant kelp *Macrocystis pyrifera*, which grows in beds that are from 50 feet to 1 mile wide and several miles long. This seaweed, which grows in the waters off Southern California and to the south, is gathered by means of special harvesting vessels equipped with mechanical cutting and loading equipment.

Green's cold process is used on the West Coast for processing *Macrocystis*.

Algin is a hydrophilic derivative of alginic acid. This natural colloid is a polyuronic acid composed of β-(1-4) linked anhydro D-mannuronic acid and anydro L-guluronic acid.

One of the most important uses of algin is as a stabilizer to give smooth body and texture to ice cream. In addition, it has hundreds of other uses in the food, pharmaceutical, cosmetic, and industrial fields.

Carrageenan.—The primary source of carrageenan is Irish moss (*Chondrus crispus*), which grows along the North Atlantic Coast. The mosslike alga is generally harvested by men working from dories and using lead-weighted rakes from 15 to 20 feet long.

Carrageenan is extracted from the Irish moss by hot water. The extractive is recovered from solution either by drying the solution on hot rolls or by precipitating it with isopropyl alcohol.

The hydrocolloid carrageenan is a galactosan sulfate having two fractions: kappa and lambda. Both kappa and lambda fractions can be divided into two or more distinct subfractions. A third major type of carrageenan, iota carrageenan, occurs mainly in the red seaweed *Eucheuma spinosum*.

Carrageenan is used primarily in nonsettling chocolate milk drinks and other foods as well as in various pharmaceuticals, such as hand lotions and toothpastes.

ACKNOWLEDGMENTS

American Agar and Chemical Company, San Diego, California, supplied the photographs on agar; Kelco Company, San Diego, California, supplied those on algin; and Marine Colloids, Inc., Springfield, New Jersey, supplied those on carrageenan. We are grateful for the cooperation extended by these organizations.

SELECTED REFERENCES

(* = not cited in text)

American Agar and Chemical Company.
N.d. The story of agar. American Agar and Chemical Company, San Diego, Calif., 10 pp.

Chapman, Valentine Jackson.
1952. Seaweeds and their uses. Pitman Publishing Corporation, New York, 273 pp.

*Conway, Elsie, and E. Gordon Young.
1966. Seaweed. Science 151(3708): 358-359.

de Virville, Davy, and J. Feldman (editors).
1964. Proceedings of the Fourth International Seaweed Symposium. The Macmillan Company, New York, 467 pp.

*Durrant, Norman W., and Carol Jolly.
1969. Green algae, *Chlorella*, as a contributor to the food supply of man. U.S. Fish Wildl. Serv., Fish. Ind. Res. 5: 67-83.

Guiseley, Kenneth B.
1968. Seaweed colloids. *In* Raymond E. Kirk and Donald F. Othmer (editors), Encyclopedia of chemical technology, 2d edition, 17: 763-784. Interscience Publications, Inc., New York.

Idson, Bernard.
1956. Seaweed colloids: $10 million now--and growing fast. Chemical Week, July 21, pp. 57-60.

Jackson, Daniel F. (editor).
1964. Algae and man. Plenum Press, New York.

Kelco Company.
*1961. Kelco algin. Kelco Company, San Diego, Calif., 13 pp.

1968. Search in the aquasphere. Kelco Company, San Diego, Calif., 24 pp.

Københavns Pektinfabrik (The Copenhagen Pectin Factory Ltd.).
1963. Genu carrageenan. 2d edition. Dyva Bogtryk A/S, Lille Skensved, Denmark, 37 pp.

Marine Colloids, Inc.
1966a. Colloid-O-Scope. Marine Colloids, Inc., Springfield, N.J. 12(I): 1-4.

1966b. Colloid-O-Scope. Marine Colloids, Inc., Springfield, N.J. 12(II): 1-4.

1967. Colloid-O-Scope. Marine Colloids, Inc., Springfield, N.J. 13(I): 1-4.

Muncaster, Dave, and Ben Messina.
1961. Algin food gels. Food Process. 22 (11): 62-64, 66, 68.

Newton, Lily.
1951. Seaweed utilization. Sampson Low, London, 188 pp.

Nilson, Hugo, and John A. Wagner.
1959. Feeding test with carrageenan. Food Res. 24(2): 235-239.

Sanford, F. Bruce.
1958. Seaweeds and their uses. U.S. Dep. Interior, Fish Wildl. Serv., Fish. Leafl. 469, 23 pp.

*Schaeffer, Victor B.
1945. The commercial importance of seaweed gums in the United States. U.S. Dep. Interior, Fish Wildl. Serv., Fish. Leafl. 156, 5 pp.

Steiner, Arnold B., and William H. McNeely.
1951. Organic derivatives of alginic acid. Ind. Eng. Chem. 43: 2073-2077.

1954. Algin in review. *In* Advances in chemistry series, No. 11, pp. 68-82. American Chemical Society, Washington, D.C.

Stoloff, Leonard.
1954. Seaweed colloids. *In* Raymond E. Kirk and Donald F. Othmer (editors), Encyclopedia of chemical technology, 1st edition, 12: 116-125. The Interscience Encyclopedia, Inc., New York.

*Tiffany, Lewis Hanford.
1958. Algae, the grass of many waters. 2d edition. Charles C. Thomas, Springfield, Ill., 199 pp.

Tressler, Donald K., and James McW. Lemon.
1951. Marine products of commerce. 2d edition. Reinhold Publishing Corporation, New York, 782 pp.

Whistler, Roy L., and James N. BeMiller (editors).
1959. Industrial gums. Academic Press, Inc., New York, 766 pp.

Young, E. Gordon, and J. L. McLachlan (editors).
1966. Proceedings of the Fifth International Seaweed Symposium. Pergamon Press Limited, Oxford, London, 424 pp.

MS. #1955

FISHERY INDUSTRIAL RESEARCH PUBLICATIONS

Vol. 1, no. 1 (April 1962):

Economic aspects of the Pacific halibut fishery. By James Crutchfield and Arnold Zellner.

Vol. 2, no. 1 (September 1962):

Quality changes in whiting stored in ice as indicated by organoleptic and objective tests. By Joseph M. Mendelsohn and John A. Peters.

Effect of cooking methods on the sodium content of halibut, haddock, and flounder. By Bernard I. Sohn and Maynard A. Steinberg.

Proximate composition changes in sockeye salmon *(Oncorhynchus nerka)* during spawning migration. By Claude E. Thurston and H. William Newman.

Mechanically deicing and weighing groundfish at the dock in New England. By John A. Peters, Joseph W. Slavin, and Arvey H. Linda.

Methods of separation of fatty acids from fish oils with emphasis on industrial applications. By Edward H. Gruger, Jr.

Storage of fish in refrigerated sea water. 1—Quality changes in ocean perch as determined by organoleptic and chemical analyses. By Edward H. Cohen and John A. Peters.

New-type multiple debreader. By Melvin E. Waters and D. J. Bond.

Vol. 2, no. 2 (December 1963):

Economic factors related to lake trout quotas on Lake Superior. By Keith D. Brouillard.

Effect of storage in refrigerated sea water on amino acids and other components of whiting *(Merluccius bilinearis)*. By Edward H. Cohen and John A. Peters.

Drip formation of fish. 1.—A review of factors affecting drip. By David T. Miyauchi.

Storage of fish in refrigerated sea water. 2.—Quality changes in whiting as determined by organoleptic and chemical analyses. By Edward H. Cohen and John A. Peters.

Technological investigations of pond-reared fish. By Leo J. Sullivan and Harry L. Seagran.

Bibliography of publications—Division of Industrial Research, by branch, year, and author, 1955-1961 inclusive. By Virginia Whorley.

Vol. 2, no. 3 (November 1964):

Free liquid content of Gulf oysters and suggested change in standards. By Arthur F. Novak, Ernest A. Fieger, and Joseph A. Liuzzo.

Comparison of chemical and sensory tests for assessing storage life of iced calico scallops *(Pecten gibbus)*. By Melvin E. Waters.

Cholesterol content of various species of shellfish. 1.—Method of analysis and preliminary survey of variables. By Mary H. Thompson.

Evaluation of the micro-diffusion method for the determination of tertiary volatile base in marine products. By John Spinelli.

Preparation of chilled meat from Atlantic blue crab. By David H. B. Ulmer, Jr.

Observations of the "blueing" of king crab, *Paralithodes camtschatica*. By Herman S. Groninger and John A. Dassow.

Comparison of the picric acid turbidity and Nessler tests with subjective evaluations of quality of shrimp. By Mary E. Ambrose, Charles F. Lee, and Frank T. Piskur.

Economic study of sea scallop production in the United States and Canada. By Richard M. Doherty, G. Paul Draheim, Donald J. White, and Charles L. Vaughn.

Vol. 2, no. 4 (May 1965):

Technological investigations of pond-reared fish. 2.—Extension of the shelf life of buffalofish products through use of antioxidents. By R. A. Greig

Economic aspects of the U. S. albacore fishing industry. By E. A. Hale and D. B. Ferrel.

Frozen king crab *(Paralithodes camtschatica)* meat: Effect of processing conditions on fluids freed upon thawing. By Jeff Collins and Russel L. Brown.

Thiaminase activity in fish: An improved assay method. By R. H. Gnaedinger.

Drip formation in fish. 3.—Composition of drip from defrosted Pacific cod fillets. By David Miyauchi, John Spinelli, and John A. Dassow.

Vol. 3, no. 1 (December 1965):

Occurrence of pomfret *(Brama japonica)* in the Northeastern Pacific Ocean. By Charles R. Hitz and Robert R. French.

Author index of publications and addresses - 1964, Bureau of Commercial Fisheries, Branches of Economics and Technology and the Branch of Reports, Seattle. By Helen E. Plastino and Mary S. Fukuyama.

Influence of temperature on the fatty acid pattern of muscle and organ lipids of the rainbow trout *(Salmo gairdneri)*. By Werner G. Knipprath and James F. Mead.

Costs and earnings of tropical tuna vessels based in California. By Roger E. Green and Gordon C. Broadhead.

Amino acid composition of the alewife *(Alosa pseudoharengus)*. By Mary H. Thompson and Robert N. Farragut.

Vol. 3, no. 2 (July 1966):

Proximate composition of Lake Michigan alewife *(Alosa pseudoharengus)*. By Donald R. Travis.

Accumulation of organic acids during cold storage of shucked soft clams, *Mya arenaria* (L.), in relation to quality. By Baruch Rosen.

Value of menhaden fish meal as a protein supplement to cottonseed meal-corn diets fed to rats. By Robert R. Kifer, Edgar P. Young, and Kam C. Leong.

Value of menhaden fish meal as a protein supplement to meat-and-bone meal-corn diets fed to rats. By Robert R. Kifer, Edgar P. Young, and Kam C. Leong.

Value of menhaden fish meal as a protein supplement in soybean meal-corn diets fed to rats. By Robert R. Kifer, Edgar P. Young, and Kam C. Leong.

Proximate composition of Gulf of Mexico industrial fish. By Mary H. Thompson.

Vol. 3, no. 3 (December 1966):

Proximate composition of the Pacific Coast Dungeness crab *(Cancer magister)*. By Robert N. Farragut and Mary H. Thompson.

Microbial analyses of frozen raw breaded shrimp. By Bobby J. Carroll, Travis D. Love, Benjamin Q. Ward, and Melvin E. Waters.

Recent technological studies of Dungeness crab processing. Part 4 - Preliminary report on salt uptake and heat penetration in whole cooked crab. By Harold Barnett and Richard W. Nelson.

Commercial fisheries of the Columbia River and adjacent ocean waters. By A. T. Pruter.

Vol. 3, no. 4 (May 1967):

Extending the shelf life of frozen cisco *(Coregonus artedii)* product through the use of water-soluble antioxidants. By R. A. Greig, J. A. Emerson, and G. W. Fliehman.

Technological studies of Dungeness crab processing. Part 3—Laboratory experiments in the control of drain time. By Harold Barnett, Richard W. Nelson, and John A. Dassow.

Temperature, weight, and drip changes during precooking of tuna. By Alexander M. Dollar, Andrew Goldner, and Harold S. Olcott.

Efficacy of fish oils in healing wounds and burns. By Maurice E. Stansby, Paul E. Zollman, and R. K. Winkelmann.

Chemical composition of commercially important fish of the United States. By Maurice E. Stansby and Alice S. Hall.

Author index of publications and addresses - 1965, Bureau of Commercial Fisheries, Division of Economics and Branches of Reports (Seattle) and Technology. By Helen E. Plastino and Mary S. Fukuyama.

l. 4, no. 1 (December 1967):

Relation of quality of canned yellowfin tuna *(Thunnus albacares)* to length of fish, time of holding on deck, frozen storage aboard vessel, and biochemical variables. By W. Duane Brown, Roland Finch, Tai-Wan Kwon, H. S. Olcott, and M. B. Schaefer.

Extending the shelf life of frozen chub *(Leucichthys hoyi)* fillets through the use of ascorbic acid dips. By R. A. Greig.

Control of Salmonellae in fish meal. By B. J. Carroll and B. Q. Ward.

Irradiation of Pacific Coast fish and shellfish. 6–Pretreatment with sodium tripolyphosphate. By J. Spinelli, G. Pelroy, and D. Miyauchi.

Extending the shelf life of frozen white bass *(Roccus chrysops)* through the use of ascorbic acid dips. By R. A. Greig.

Relative catching efficiency of a 70-foot semiballoon shrimp trawl and a 94-foot Eastern fish trawl. By Walter T. Pereyra, Hiromu Heyamoto, and Robert R. Simpson.

ol. 4, no. 2 (April 1968):

Proximate composition and sodium and potassium contents of four species of tuna. By Neva L. Karrick and Claude E. Thurston.

Use of sodium acid pyrophosphate to retain natural moisture and reduce struvite in canned king crab *(Paralithodes* ssp.). By Robert Jones.

Mechanized haul seine for use in farm ponds. By Kenneth L. Coon, Alfred Larsen, and James E. Ellis.

ol. 4, no. 3 (June 1968):

Effect of special handling of haddock on the postirradiation shelf life of haddock fillets. By Vincent G. Ampola and Louis J. Ronsivalli.

Sonic system for determining distances between selected points of an otter trawl. By Leon E. French, Jr.

Echo reflector for sonic measuring system on an otter trawl. By Leon E. French, Jr.

ol. 4, no. 4 (July 1968):

Effect of gamma radiation on thiaminase activity in fresh-water fish. By Richard A. Krzeczkowski.

Relation of temperature, time, and moisture to the production of aflatoxin in fish meal. By Travis D. Love.

Variation in the fatty acid composition of Pacific herring *(Clupea harengus pallasi)* oil in Alaska during 1964 and 1965. By Paul A. Robisch and Edward H. Gruger, Jr.

Author index of publications and addresses — 1966, Bureau of Commercial Fisheries Branch of Technology and Branch of Reports (Seattle). By Helen E. Plastino and Mary S. Fukuyama.

ol. 4, no. 5 (December 1968):

Shrimp-behavior studies underlying the development of the electric shrimp-trawl system. By Edward F. Klima.

Designing an improved California tuna purse seine. By M'nakhem Ben Yami and Roger E. Green.

ol. 4, no. 6 (February 1969):

Rapid method for the estimation of EDTA (Ethylenediaminetetraacetic acid) in fish flesh and crab meat. By Herman S. Groninger and Kenneth R. Brandt.

Design, construction, and field testing of the BCF electric shrimp-trawl system. By Wilber R. Seidel.

Care of fish holds. By Wayne I. Tretsven.

ol. 4, no. 7 (March 1969):

Opening oysters and other bivalves using microwave energy. By Joseph M. Mendelsohn, Louis J. Ronsivalli, Frederick J. King, Joseph H. Carver, Robert J. Learson, Barry W. Spracklin, and Ernest M. Kenyon.

A new approach for evaluating the quality of fishery products. By Robert J. Learson and Louis J. Ronsivalli.

Demersal fish resources: Composition, distribution, and commercial potential of the Continental Shelf stocks off Southeastern United States: By Paul Struhsaker.

Vol. 5, no. 1 (May 1969):

Problem of "green" frozen raw breaded shrimp. By Mary H. Thompson and Robert N. Farragut.

Improved method for producing pindang. By Sofjan Iljas and Louis J. Ronsivalli.

Irradiation of Pacific Coast fish and shellfish. 7–Storage life at 33° F. of irradiated and repacked meat of Dungeness crab. By F. M. Teeny, D. Miyauchi, and G. Pelroy.

Fish oils–Fatty acid composition, energy values, metabolism, and vitamin content. By Robert R. Kifer and David Miller.

Vol. 5, no. 2 (July 1969):

Proximate composition of commercial fishes from the Mediterranean Sea and the Red Sea. By A. Herzberg and Rachel Pasteur.

Green algae, *Chlorella*, as a contributor to the food supply of man. By Norman W. Durrant and Carol Jolly.

Explorations for calico scallop, *Pecten gibbus*, in the area off Cape Kennedy, Florida, 1960-66. By Shelby B. Drummond.

Vol. 5, no. 3 (August 1969):

Use of sodium tripolyphosphate to control fish shrinkage during hot-smoking. By Harold J. Barnett, Richard W. Nelson, and John A. Dassow.

Use of electron paramagnetism in research on fish lipids. By William T. Roubal.

Evaluation of muscle hypoxanthine and volatile bases as potential quality indices for industrial bottomfishes from the Gulf of Mexico. By Enrique J. Guardia and Gerhard J. Haas.

Relative chemical composition and nutritive values of king crab, *Paralithodes camtschatica*, and blue crab, *Callinectes sapidus*. By Robert R. Kifer and Paul E. Bauersfeld.

Vol. 5, no. 4 (October 1969):

Value of menhaden, *Brevoortia tyrannus*, meal as a protein supplement to cottonseed meal-corn diets for pigs. By Robert R. Kifer and Edgar P. Young.

Uptake of oxygen in refrigerated radiopasteurized fish. By L. J. Ronsivalli and B. L. Tinker.

Test-tank studies of shrimp-pot efficiency. By Doyne W. Kessler.

Distribution of royal-red shrimp, *Hymenopenaeus robustus*, on three potential commercial grounds off the Southeastern United States. By Richard B. Roe.

Effect of varying the extraction procedure on the protein extractability of frozen-stored fish muscle. By Elinor M. Ravesi and Margaret L. Anderson.

Vol. 5, no. 5 (December 1969):

Alaska pink shrimp, *Pandalus borealis*: Effects of heat treatment on color and machine peelability. By Jeff Collins and Carolyn Kelley.

Depth-time sequence analyses of the operation of two California tuna purse seines. By Roger E. Green.

Recommendations for improving the quality of vessel-caught groundfish. By J. Perry Lane.

Author index of publications and addresses — 1967, Bureau of Commercial Fisheries Branch of Technology and Branch of Reports (Seattle). By Helen E. Plastino and Mary S. Fukuyama.

MANUSCRIPTS APPROVED
FOR PUBLICATION IN *FISHERY INDUSTRIAL RESEARCH*

DIVISION OF FOOD SCIENCE

Title and author(s)	Laboratory[1]
Recommendations for the sanitary operation of plants that process fresh and frozen fish. By J. Perry Lane.	Gloucester
Preliminary study of the proximate composition of fur seal, *Callorhinus ursinus*, meat. By Richard W. Nelson and Harold J. Barnett.	Seattle
Composition of Tennessee River fish and fishery products. By Richard A. Krzeczkowski.	Ann Arbor

[1] For further information about these papers, please contact the Laboratory Director at the appropriate address:

Laboratory Director
Bureau of Commercial Fisheries
Technological Laboratory
Emerson Avenue
Gloucester, Massachusetts 01930

Laboratory Director
Bureau of Commercial Fisheries
Technological Laboratory
2725 Montlake Boulevard East
Seattle, Washington 98102

Laboratory Director
Bureau of Commercial Fisheries
Technological Laboratory
P.O. Box 640
Ann Arbor, Michigan 48107

DIVISION OF EXPLORATORY FISHING

Title and author(s)	Office[1]
Machine for separating northern shrimp, *Pandalus borealis*, from fish and trash in the catch. By Michael G. Corbett.	Gloucester
A tow bar system for seining farm ponds. By Kenneth L. Coon and James E. Ellis.	Ann Arbor

[1] For further information about these papers, please contact the Base Director at the appropriate address:

Base Director
Bureau of Commercial Fisheries
Exploratory Fishing and Gear Research Base
State Fish Pier
Gloucester, Massachusetts 01930

Base Director
Bureau of Commercial Fisheries
Exploratory Fishing and Gear Research Base
P.O. Box 640
Ann Arbor, Michigan 48107

SUGGESTIONS TO AUTHORS WRITING FOR *FISHERY INDUSTRIAL RESEARCH*

by F. Bruce Sanford, Lena Baldwin, and Mary S. Fukuyama

A. APPROACH

Write your paper for a reader who has had advanced scientific training. Organize and write it in such a way that he can read it rapidly, yet understand it the first time through.

B. COMPONENTS OF THE PAPER

1. Title

Select a title that reveals the overall purpose of your research. When appropriate, include scientific names of species.

2. Abstract

Make the abstract semidescriptive: tell what the report is about, and end with a statement of your overall conclusion. (This conclusion will answer the question stated, or implied, by your overall purpose.) Keep the abstract short, but do not use the title of the paper as the assumed antecedent of otherwise irreferable pronouns.

3. Contents

Include a table of contents.

4. Introduction

In the introduction, (1) orient the reader to your overall purpose, (2) state the purpose explicitly, (3) orient the reader to the subpurposes, and (4) end with a listing of the subpurposes.

Include in each orienting discussion all the important words that will occur in the subsequent statement of purpose. Avoid unnecessary reviews and economic data.

When stating the overall purpose, include a word such as "purpose" so that the reader can quickly identify the statement for what it is.

5. Main Divisions

Do not use such generalized divisions as "Experimental." Instead, be specific by making the main divisions of the paper correspond to the main divisions of your research—Experiment I, Experiment II, and so on. Give each experiment a specific title so that the reader will gain immediate insight into the scope of the experiment.

For main divisions, do not use "Materials," "Procedures," and "Results" (except when, as is rare, your paper reports only a single unit of research, such as Experiment I); instead, use these headings for minor divisions. When you use them, consider the following suggestions:

a. Materials and methods.—Describe in detail the materials and the methods used in your first experiment. If the materials and methods used in succeeding experiments are similar to those in the first, merely describe the differences when you report the succeeding experiments.

If a method includes several closely consecutive steps, number them and write out the steps; use the active voice —for example, "In the separation of acids from the aqueous phase, the analyst:

1. Neutralized a 1-milliliter portion of the aqueous layer to a pH of 10 with 0.1 N NaOH.
2. Transferred the neutralized solution to Flask A.
3. Placed Flask A in a bath . . . ."

b. Results.—Report all numerical data in tables and graphs—avoid cluttering the text with numbers. In the discussion of results, do not repeat the data that are contained in the tables and graphs. Instead, analyze the data by pointing out significances and implications. Use summary tables; do not overwhelm the reader with unnecessary tables of raw data.

6. Conclusions

Draw conclusions from your results. Make sure that the overall conclusion and the subconclusions correspond with your overall purpose and subpurposes. Present the conclusions in logical sequence.

7. Summary

End the report with a summary. Make the summary quantitative, not merely descriptive. If the report is short, end it with "Summary and Conclusions." If it is long, separate the two.

8. Acknowledgment

Avoid titles of individuals—such as mister, doctor, or professor. Simply acknowledge the assistance received.

9. Literature Cited

Make your citations complete and accurate so the reader can find the original with ease. Follow the format used in *Fishery Industrial Research.*

C. MECHANICS

1. Abbreviations

Avoid abbreviations unless you have compelling reason to use them—for example, if you lack space in your tables. If you use abbreviations, use the ones standard in your discipline. End the abbreviation with a period. See the latest issue of *Fishery Industrial Research.*

2. English Usage, Punctuation, and Capitalization

Meticulously follow established practice in grammar, punctuation, and capitalization. For precise, forceful statements, use personal pronouns where appropriate and thereby avoid illogical constructions or ambiguities.

3. Headings

Use the system of headings shown in the latest edition of *Fishery Industrial Research.*

4. Numbers

Use Arabic numbers unless you have a compelling reason to use Roman numbers or to write the numbers out. See the latest issue of *Fishery Industrial Research.*

5. Tables and Graphs

a. Tables.—Number each table and give it a title. (The title, placed at the top of the table, is a brief statement of such applicable referents as the nature, classification, or chronology of the information presented, and the political division, geographical area, or physical plant to which the data refer. These points are sometimes referred to as the "what," "how classified," "when," and "where" of the table.) Do not place a period at the end of the title. When headings apply to information in more than 1 column, word them so that they reveal the meaning of the data in all columns covered. Place all units of measurement over figure columns, and underline. Separate all columns with vertical lines, but use horizontal lines and footnotes sparingly. Place each table on a separate page. See the latest issue of *Fishery Industrial Research.*

b. Graphs.—Number each graph. Place the title at the bottom of the graph, and end it with a period. In wording the title, follow the suggestions for titles of tables. Frame all 4 sides of the graph. Place tick marks on the inside of the frame at only the left and bottom sides unless you have compelling reason to do otherwise. Identify ordinate and abscissa; capitalize all letters in the identification. Place units of measurement in parentheses, and print them in lower case. Unless it clutters the graph, label each curve directly instead of using a legend or a key. Place each graph on a separate page. See the latest issue of *Fishery Industrial Research.*

CONTENTS

GPO 996-87

UNITED STATES
DEPARTMENT OF THE INTERIOR
U.S. FISH AND WILDLIFE SERVICE
BUREAU OF COMMERCIAL FISHERIES
DIVISION OF PUBLICATIONS
BLDG. 67, U.S. NAVAL AIR STATION
SEATTLE, WASHINGTON 98115

OFFICIAL BUSINESS

Return this sheet to above address, if you do NOT wish to receive this material ☐, or if change of address is needed ☐ (indicate change and give ZIP Code).

POSTAGE AND FEES PAI
U.S. DEPARTMENT OF THE IN

FISHERY INDUSTRIAL RESEARCH

VOLUME 6 NO. 2

United States
Department of the Interior
U.S. Fish and Wildlife Service
Bureau of Commercial Fisheries

Members of the fishing industry and allied interests who wish to receive FISHERY INDUSTRIAL RESEARCH should write to:

Bureau of Commercial Fisheries
Division of Publications
Bldg. 67, U.S. Naval Air Station
Seattle, Washington 98115

UNITED STATES DEPARTMENT OF THE INTERIOR
Walter J. Hickel, *Secretary*
Fred J. Russell, *Under Secretary*
Leslie L. Glasgow, *Assistant Secretary for Fish and Wildlife and Parks*

U.S. FISH AND WILDLIFE SERVICE
Charles H. Meacham, *Commissioner*

BUREAU OF COMMERCIAL FISHERIES
Philip M. Roedel, *Director*

FISHERY INDUSTRIAL RESEARCH
Volume 6 -- Number 2

Washington, D. C.
MAY 1970

As the Nation's principal conservation agency, the Department of the Interior has basic responsibilities for water, fish, wildlife, mineral, land, park, and recreational resources. Indian and Territorial affairs are other major concerns of America's "Department of Natural Resources."

The Department works to assure the wisest choice in managing all our resources so each will make its full contribution to a better United States — now and in the future.

MACHINE FOR SEPARATING NORTHERN SHRIMP, *Pandalus borealis,* FROM FISH AND TRASH IN THE CATCH

by

Michael G. Corbett

ABSTRACT

Because of the labor required in separating northern shrimp from the unwanted components of the catch that are taken along with it, this valuable resource in the Gulf of Maine is not harvested to the extent possible. Consequently, a machine was developed to separate the shrimp from the bulk of groundfish and other species taken in trawl catches during exploratory and commercial fishing. Its use eliminates the laborious task of sorting the catch by hand, yet the separator recovers about 95 percent of the shrimp that are fed into it, while eliminating about 90 percent of the trash.

CONTENTS

Author: Michael G. Corbett, *Mechanical Engineer*, Bureau of Commercial Fisheries Exploratory Fishing and Gear Research Base, State Fish Pier, Gloucester, Massachusetts 01930.
Published March 1970.

INTRODUCTION

Northern shrimp is a valuable resource in the Gulf of Maine. An estimated 14 million pounds were landed during the 1968 season, substantially more than the previous year. This resource is harvested by bottom trawling, much of it in areas inhabited by finfish and other species of shellfish.

Many of these areas, such as Stellwagen Bank (Figure 1) and that west of Jeffreys Ledge, having good commercial concentrations of shrimp are passed over at times because of the amounts of associated species likely in the catch. Tows often produce an equal weight of finfish.

The amount of associated species taken during a tow will vary depending on the time of year. During the peak of the shrimp season, January through March, catches are generally cleaner than at other times of the year. The relatively clean catches during this peak make hand picking, the current method of separating the shrimp from the associated species or "trash," possible. At other times of the year, hand picking is a time-consuming, laborious task that often is not economically feasible. If hand picking is not done, or is done in a haphazard manner, the buyer usually subtracts a percentage from the exvessel price paid as a trash allowance. Also, some vessels leave the shrimp fishery during the shrimp season and fish alternate resources mainly because of the relatively large amounts of trash present in the catch in the fall at the beginning of the season and in the spring near the end of the season.

Investigations and test fishing done prior to the exploratory shrimp fishing program undertaken by the Exploratory Fishing and Gear Research Base at Gloucester, Massachusetts, indicated that the program could be hampered and the work made more difficult without a suitable alternative to hand picking.

The need in exploratory and commercial fishing for a more efficient method led to the development of a shrimp separator (Figure 2). This machine mechanically separates shrimp from other components of the catch and thereby eliminates the need for hand picking.

Because of the potential value of the shrimp separator to the commercial fishing industry, the purpose of this report is to make information on the machine available.

I. DESCRIPTION OF SHRIMP SEPARATOR

This part of the report describes the operation of the separator and its design (Figure 3).

A. OPERATION

The shrimp separator, which was designed for use as shipboard equipment to be installed on the deck near the place where the net is emptied (Figures 4 and 5), is potentially usable as part of an automated system on deck or in a processing plant on shore, or it can be used independently.

We, the staff of the Exploratory Fishing and Gear Research Base at Gloucester, have not had the opportunity to use the shrimp separator in an automated system, so we use the machine as an independent entity.

The machine operates as follows. When the catch is shoveled into a hopper (Figure 6), an angle board inside the hopper forces the catch against a feed door, which, when lifted, allows the catch to tumble onto a separating platform. Two eccentric shafts, one supporting each end of the platform, provide: (1) the up-and-down movement necessary to cause the shrimp to be separated from the trash and (2) the throwing action needed to move the shrimp and the unwanted portion of the catch along the netting (Figure 7) until the shrimp fall through the netting and the unwanted portions fall over the end of the platform into a receiving box.

The shrimp, after passing through the netting, fall into the three wooden fish boxes of

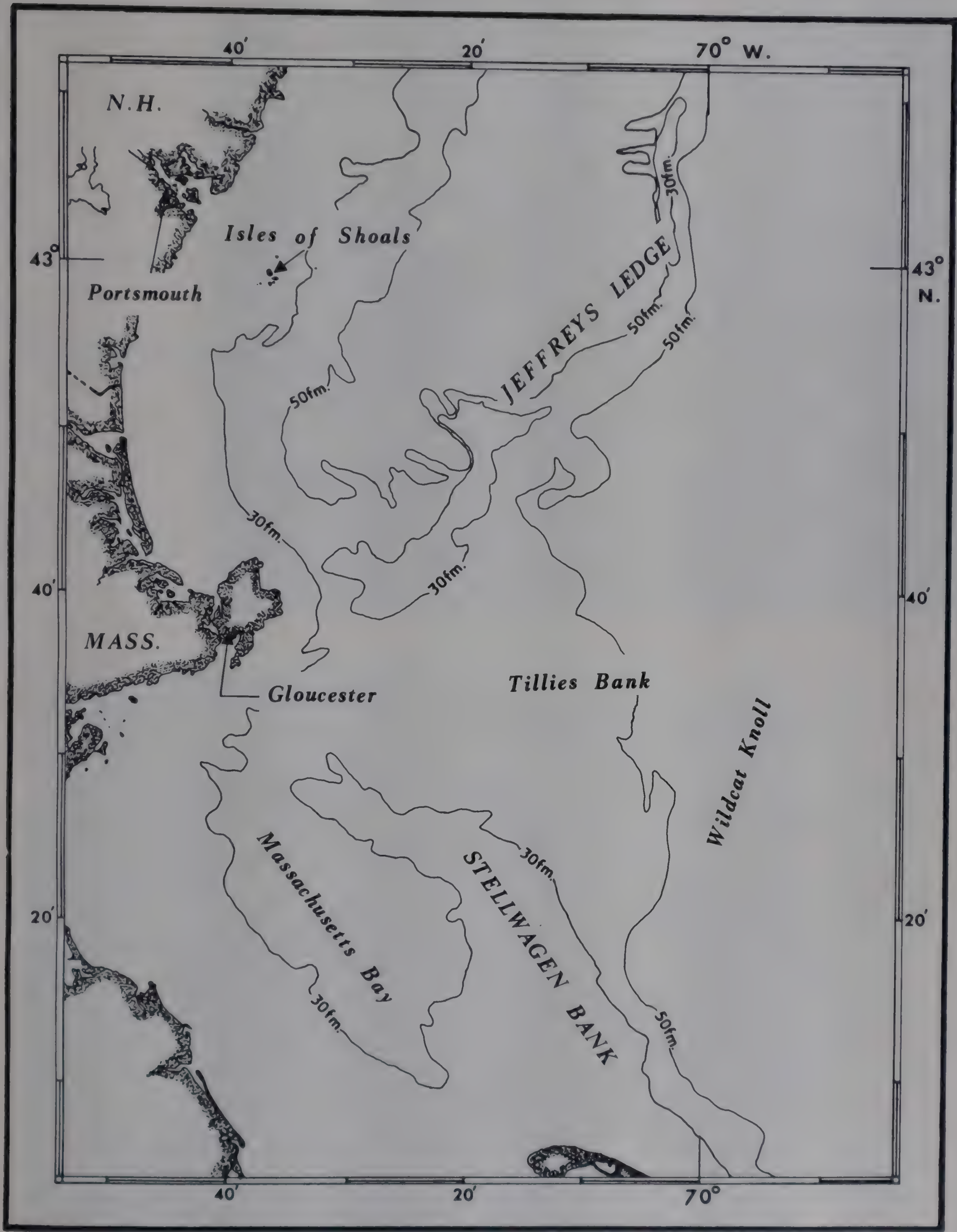


Figure 1.–Map of Gulf of Maine.

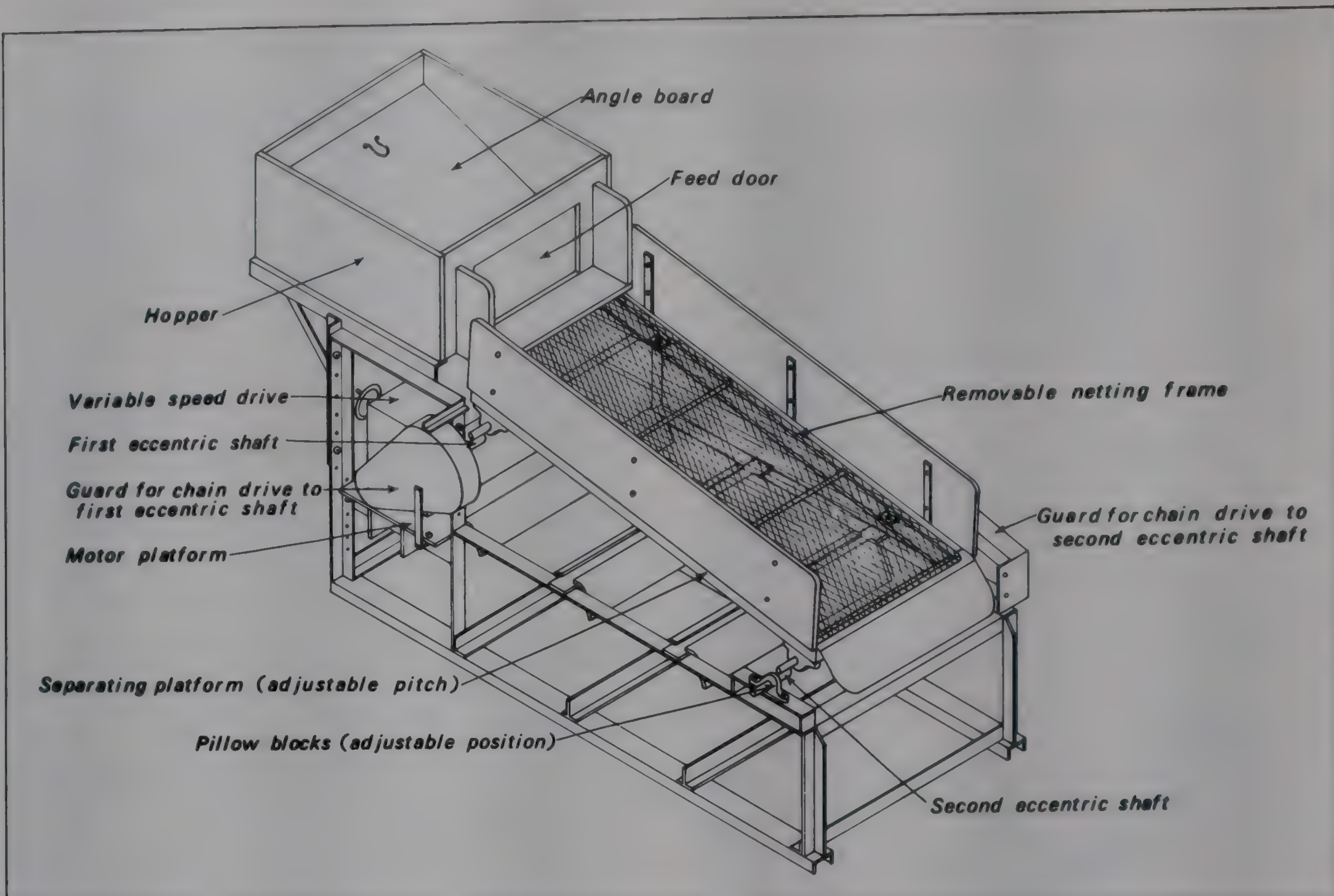


Figure 2.–Shrimp separator (isometric view).

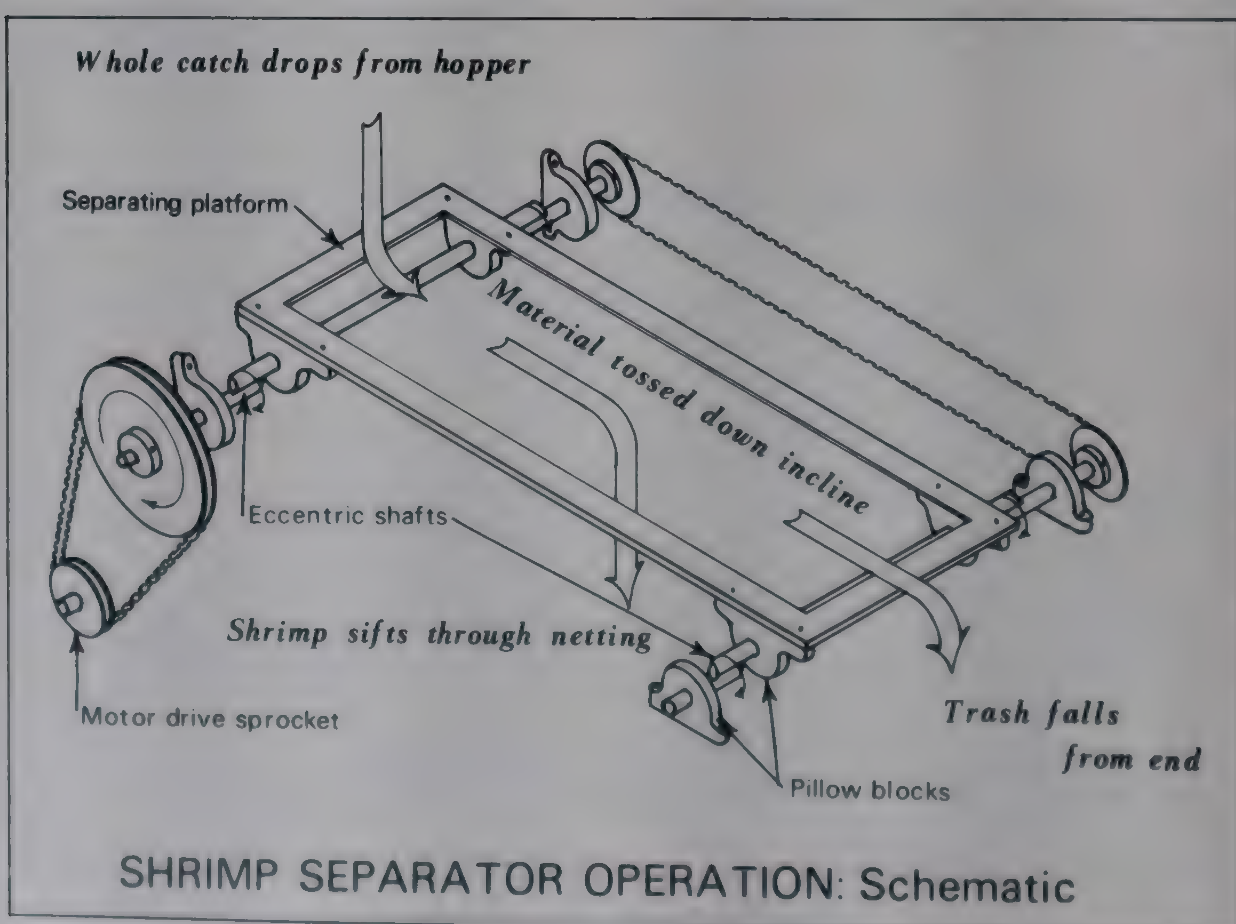


Figure 3.–Shrimp separator schematic.

Figure 4.–Cod end being brought aboard.

Figure 5.–Catch of shrimp in checker.

Figure 6.—First shovel full into separator.

Figure 7.—Separator in operation.

standard size. Each box is 29 inches long, 17½ inches wide, and 12½ inches high, and each will hold 130 pounds of shrimp. The boxes can be inserted and removed from either side of the machine (Figure 8).

B. DESIGN

This section of the report describes the present design of the shrimp separator and then indicates how the design might be made more economical.

1. Present Design

Described here are the source of power, the variable-speed drive, the chain and eccentric shafts, and the separating platform.

a. Source of power.—The shrimp separator can be driven by almost any source of power delivering about 1 horsepower. Our model, because of the particular source of power that was readily available to us, is driven by a reversible hydraulic motor mounted below the hopper (Figure 8).

b. Variable-speed drive.—A mechanical variable-speed drive, which allows adjustment for catches of different composition, is directly connected to the motor with a flexible coupling. Because the speed is variable, the best speed can be selected for the maximum separation of shrimp with the minimum amount of small trash passing through the netting.

c. Chain and eccentric shafts.—Power is transferred by a chain to a sprocket attached to an eccentric shaft at one end of the separating platform. This shaft, with a 1-inch eccentric, turns, by means of another chain, a second shaft, also with a 1-inch eccentric, at the other end of the platform. Together they impart the rotary motion that, as was indicated earlier, gives (1) the up-and-down movement necessary for separation and (2)

Figure 8.–View of separator showing hydraulic motor and wood fish boxes in place.

the throwing action necessary to move the catch along the platform.

d. Separating platform.—Described in this subsection are (1) the pitch of the separating platform, (2) its dimensions, and (3) its openings.

(1) Pitch.—The pitch of the separating platform is adjustable through five positions between 0° and 12° to the horizontal. These positions allow the operator to change the speed at which the catch moves along the platform, without altering the movement up and down that is necessary to separate the shrimp. The effectiveness of the lateral motion for moving material along the platform is controlled by the angle of slope.

(2) Dimensions.—The separating platform is 57 inches long and 24 inches wide and is fitted with sideboards to contain the catch. This size handles the amount that two men can shovel into the hopper and allows easy movement of the catch along the platform with maximum separation of unwanted fish and trash and minimum loss of shrimp over the end.

(3) Openings.—The shrimp can be separated from the unwanted material by means of netting with mesh of suitable size or by means of steel rods suitably spaced.

(a) *Netting.*—The separating platform has a quick-release netting frame that allows the size of mesh and the configuration of the mesh to be changed to accommodate shrimp of different sizes. The shrimp can be graded to size by the use of mesh of smaller size in the first sections of the netting frame. Experiments have shown, however, that even when only one size of mesh is used, some grading occurs, because the small shrimp tend to fall through the net sooner than the large shrimp do. A 2-inch square mesh was most satisfactory, effectively separating out from the catch about 95 percent of the shrimp that have an average count of 30 to 60 per pound, heads on. The other 5 percent of the shrimp fell over the end of the platform into a box for trash.

The fish boxes are not filled at a uniform rate. The first box, which is the one nearest to the hopper, fills about five times as fast as the third box does, and the second box fills about three times as fast as the third box. This difference in the rate of fill could undoubtedly be narrowed considerably by varying the size of mesh as described above. We have not as yet had the opportunity to investigate the best combination of mesh size.

(b) *Steel rods.*—As an alternative to the netting, $\frac{3}{16}$-inch diameter steel rods, which ran the length of the platform, were welded to the netting frame. The rods were spaced 1 inch on center and then plastic-coated to a maximum thickness of $\frac{1}{16}$ inch. The rods were equally as effective as the netting was and did not require periodic adjustment as did the netting. After observing the rods in use, we feel, however, that a longer platform than the existing 57-inch one would have improved the performance of the rods.

2. Future Design

This section discusses how the separator could be made more economically. It considers the following factors that affect the cost: (a) adjustable features, (b) structural strength, (c) power, and (d) size and configuration.

a. Adjustable features.—Because anticipating design requirements was difficult with a machine of this type, we incorporated several adjustable features. These features include reversible rotation, adjustable platform angle, variable speed, and interchangeable screens having different sizes of mesh and rods.

(1) Reversible rotation.—The reversible rotation, which was provided to slow the descent of the catch along the platform, proved to be unnecessary for our purposes but may be useful in other fisheries for the separation of different species.

(2) Adjustable platform angle.—For the platform angles tested, a fixed inclination of 10° to 12° for the platform was satisfactory. Thus, an adjustable platform angle could be eliminated in future models.

(3) Variable speed.—The wide range of 50 to 300 revolutions per minute for the rotation of the eccentric shaft at the separating platform is more than adequate because the optimum speed of operation was found to be about midrange (175 revolutions per minute plus or minus 25 revolutions per minute). This range of 150 to 200 revolutions per minute is necessary to compensate for the variable amount of trash and size of shrimp in the catch.

(4) Variable-mesh screens. — Because the size of the shrimp will vary, interchangeable screens with mesh of varying size are desirable. Some of our best results were obtained with 2-inch square mesh, but various combinations of mesh size could be tried (between 1½-inch to 2½-inch square mesh). Equally as effective were the plastic-coated steel rods that were described earlier.

b. Structural strength.—Structurally, the machine is stronger than is necessary because the working loads are lighter than we anticipated they would be. Construction is primarily of 2 by 2 by ⅜-inch steel angle iron. A marked reduction in the size of stock is not advisable, however, unless tolerances can be held during construction. The reason for not reducing the size of stock is that stresses due to the possible misalignment of rotating components could cause their deformation and the failure of welds. Furthermore, structural overdesign helps to ensure constant operation under the rigorous conditions of commercial fishing.

c. Power.—Operating experience indicates that a motor of 1 horsepower would provide sufficient power. We used a much higher horsepower hydraulic motor because it was readily available to us.

d. Size and configuration.—The size and general configuration of the separator were determined by the space available aboard our particular vessel. Overall dimensions are: length - 98 inches, width - 40½ inches, height - 52 inches. Changing the size would alter the characteristics of the operation. Shortening the separating platform less than the present 57 inches would not be advised unless the rate of descent of the catch is slowed.

II. EVALUATION OF SHRIMP SEPARATOR

As was indicated, the separator described here was constructed to meet our own needs. For this purpose, it performed better than we expected, demonstrating its usefulness and effectiveness in trial use and subsequently in three shrimp-survey cruises. To perform the quantitative testing required to give a complete report of performance under a comprehensive range of catch conditions, we would have had to use our vessel longer than it could have been spared, so we were unable to evaluate the separator under all conditions. Based, however, on observations made in the three survey cruises, where the separator was used for over 100 tows, we estimate that about 95 percent of the shrimp and 10 percent of the trash passed through the screen. This 10 percent of the trash consisted primarily of small starfish with a few small flatfish and herring mixed in.

The rate of separation by the experimental model was limited by the speed at which two men shoveled the shrimp into the hopper and by the slope of the screen. The separator generally processed an average catch of 20 bushels in less than 15 minutes. The rate of separation, of course, varied according to the amount and type of trash in the catch.

The shrimp separator has the potential of general use. If, for example, it were made in several sizes, the separator would be usable on vessels of various sizes. Because it is essentially a piece of processing equipment, it could also have applications in processing plants onshore.

SUMMARY

Northern shrimp are not harvested to the extent possible, because too much time and labor are required in separating the shrimp from the unwanted components of the catch. The purpose of this article is to report on a machine that separates the shrimp rapidly and efficiently.

In the operation of the separator, the catch is shoveled into a hopper, which feeds the shrimp onto a vibrating separatory platform. This platform is made up of netting or rods with openings sufficiently large to allow the shrimp to fall through into boxes below but sufficiently small to retain most of the other materials in the catch. The platform is set at such an angle and is given sufficient motion that the shrimp are separated out and the materials that do not fall through the net move along to where they fall over the edge of the platform into a receiving box.

The design of the separator is simple and straightforward. It can be driven by any motor capable of delivering 1 horsepower. The motor is directly coupled to a mechanical variable-speed drive. Power is transferred to the separating platform by means of a chain to an eccentric shaft at the upper end of the platform. The eccentric shaft at the lower end of the platform is linked by chain to the upper shaft to ensure a coordinated pattern of motion. The pitch of the platform is adjustable between 0° and 12° to the horizontal. The platform has a quick-release netting frame that allows the size of mesh or rods and their spacing to be changed to accommodate shrimp of various sizes.

The separator described here was made from mechanical parts that were readily available to us and that would fit our particular use. A commercially designed separator, however, could be made more cheaply than ours was by using more economical parts and by eliminating unnecessary features. Reversible rotation, for example, is not required for northern shrimp. The platform angle need not be adjustable but can be fixed at an inclination of 10° to 12°. The range of variable speed can be narrowed considerably to 175 revolutions per minute plus or minus 25 revolutions per minute. The machine is stronger than is necessary, because the weights of the working loads are less than we anticipated that they would be. The machine also is overpowered, so a smaller power unit of about 1 horsepower could be used.

In trials at sea, the shrimp separator worked well. It generally processed an average catch of 20 bushels in less than 15 minutes, and it satisfactorily separated out about 95 percent of all the shrimp able to pass through the size of mesh used, while eliminating about 90 percent of the trash. The separator could have application not only aboard ship but in processing plants on shore.

MS. #1907

RECOMMENDATIONS FOR THE SANITARY OPERATION OF PLANTS THAT PROCESS FRESH AND FROZEN FISH

by

J. Perry Lane

ABSTRACT

The problem of sanitation in food-processing plants is receiving increasing attention from Federal and State regulatory agencies, as well as private industry. This article covers recommended guidelines that can assist the processors of fresh and frozen fish in evaluating their existing sanitation practices or in establishing new ones.

CONTENTS

Author: J. Perry Lane, *Supervisory Research Food Technologist*, Bureau of Commercial Fisheries Technological Laboratory, Emerson Avenue, Gloucester, Massachusetts 01930.

CONTENTS—Con.

INTRODUCTION

In recent years, the spotlight of public attention has focused on the operations of food processors. This spotlight has shown on fish processors, as is evidenced by the succession of bills on compulsory inspection and regulation of the seafood industry that have recently been introduced in the Congress of the United States. These bills are concerned primarily with protecting the consumer from health hazards and aesthetically undesirable practices. For the most part, the need for protection results from problems in sanitation.

The guidelines presented here represent an attempt to assemble the existing requirements for food plants in general and to relate them to fish plants in particular. A processor of fresh fish may find that many of the suggestions are difficult to put into practice without rebuilding his plant. These suggestions or closely related ones, however, are actual requirements for some food processors, such as packers of meat and poultry and producers of dairy products. So, similar types of regulations are likely to be forthcoming for the fishing industry. These guidelines thus can serve as a preview of some of the things that may be required.

Apart from any regulatory activities, another powerful factor now at work suggests that the fish processor should take a lively interest in sanitation. This factor is the consumer's increased awareness of quality factors and processing conditions. With the

elimination of the captive Friday market for fishery products, seafoods have to compete on their own merits for the consumer's food dollar. The fishing industry, therefore, is fortunate in having a product that is both nutritious and flavorful when it is handled properly.

The purpose of these guidelines is to provide the processor with suggestions that will help him to give the consumer the quality that makes fish a desirable food. Some of the suggestions can be put into practice immediately, whereas others, such as those that involve building construction, can aid in long-range planning for expansion or remodeling. Every segment in the chain of distribution from the sea to the consumer must ensure that it delivers fish that is as close as possible to the quality that it received. By paying proper attention to sanitation in his plant, the processor will contribute greatly toward maintaining the quality of the fish.

The first part of the guidelines presented here gives recommendations for the plant; the second part gives recommendations for the processing of the fish.

I. PLANT RECOMMENDATIONS

In this part of the guidelines, we are concerned with plant premises and plant construction.

A. PLANT PREMISES

Both the location of the plant and the plant surroundings are important factors in a sanitary food-processing operation.

1. Location

a. If possible, locate the plant away from such sources of odors, dust, and air contamination as refineries, chemical plants, and dumps. [See Thompson and Farragut (1969) for an example of a problem that can be encountered at certain plant locations.]

b. Locate the plant where it will be accessible to a supply of potable (here potable means that the water supply meets the criteria in the current edition of the "U.S. Public Health Service Drinking Water Standards") water and to a sewage system.

c. Locate the plant in a well-drained area.

d. Pave the entrance roadways.

e. Physically separate the plant from any plants that process nonhuman food.

2. Surroundings

a. Keep the surroundings free of unkempt vegetation capable of harboring insects or vermin.

b. Keep the grass and shrubs trimmed and neat.

c. Keep refuse areas separate from the processing plant.

d. Do not pile waste containers and fish boxes, for example, in the open area outside of the plant.

B. PLANT CONSTRUCTION

In the construction of the plant, we are concerned with both the facilities for processing the fish and the facilities for the employees.

1. Processing Facilities

We can divide the processing facilities into what we might call the basic facilities and the equipment used in the processing operations.

a. **Basic facilities.**—What do we mean by basic facilities? We consider the basic facilities to be building construction, water supply and waste disposal, refrigeration, and lighting and ventilation.

(1) Building construction.

Construct the buildings large enough to accommodate the operation without hampering sanitary cleanup.

In areas where food is processed or stored, use building materials that are impervious to water, easily cleanable, and resistant to wear and corrosion.

Keep all exterior openings such as doors, windows, and vents in good repair, and equip them with screens or other devices, such as air curtains, to prevent the entrance of insects, rodents, and other animals.

In this section, we consider the following subjects specifically: floors, walls, ceilings, and entrances.

(*a*) *Floors.*—Two aspects of floor construction are of concern: the floors themselves and their drains.

[1] Floor construction.

Construct the floors of hard material such as waterproof concrete or tile. Do not make the floors extremely smooth. To prevent the workers' slipping on the floors, give the concrete a rough finish or use embedded abrasive particles.

Apply an approved latex synthetic resin base on concrete or mortar floors to increase resistance to corrosion.

Install drainage coves at the junctures of floors and walls.

[2] Floor drains.

In any area where water is used, install at least one drainage outlet for each 400 square feet of floor space.

Give floors a slope of ¼ inch per foot to drainage outlets.

Make the slope uniform with no dead spots.

Provide drains with traps.

In areas where the water seal in the traps is likely to evaporate unless replenished, provide the drains with removable metal screw plugs.

Construct drainage lines of galvanized iron or steel.

Use drainage lines with an inside diameter of at least 4 inches.

Vent drainage lines to outside air.

Screen the vents to prevent rodents from entering the plant.

Do not connect drainage lines from toilets to other drainage lines; be sure that the drainage lines from toilets discharge directly into a sewage system.

(*b*) *Walls.*

Make interior walls smooth and flat.

Maintain the walls in good repair.

Construct the walls of water-impervious materials, such as glazed brick, glazed tile, smooth-surfaced portland-cement plaster, or other nontoxic, nonabsorbent material. [Poured concrete walls are satisfactory if they are troweled to a smooth finish. Marine plywood or metal walls (stainless steel, aluminum, or galvanized iron or steel) also are satisfactory if seams, nail holes, and junctions of floors, walls, and ceilings are watertight.]

Do not allow the supporting structures of walls to be exposed.

(*c*) *Ceilings.*

Place ceilings in work areas in such a way as to prevent foreign material from falling from overhead pipes, machinery, and beams onto exposed fishery products.

Make ceilings 10 feet high or higher in work areas.

Construct ceilings of portland-cement plaster, large-size asbestos boards with joints sealed with a flexible sealing compound, or other suitable material impervious to moisture.

(*d*) *Entrances.*—In this section, we are concerned with the construction of doorways and doors and with pest control.

[1] Construction of doorways and doors.

Make doorways through which products are transferred on hand-trucks, dollies, or forklifts at least 5 feet wide.

Make the doors and frames of rust-resistant metal or of wood sheathed completely with rust-resistant metal having tightly soldered or welded seams.

[2] Pest control.—Both insects and rodents need to be controlled to prevent contamination and destruction of food products.

[a] Insect control.

Screen and maintain in good repair all windows, doorways, and other openings that would admit flies and other insects.

[a] Insect control—Continued

Provide "fly-chaser" fans and ducts over outside doorways in the food-handling area.

Limit the use of insecticides to those that are approved by the U.S. Food and Drug Administration.

In the application of insecticides, take care to prevent their contact with fish or other food products and with any working surfaces that come in contact with food products.

[b] Rodent control.

Provide all exterior openings with screens that are rodentproof as well as insectproof.

Except for solid masonry walls constructed or lined with such materials as glazed tile or brick, imbed expanded metal or wire of ½-inch mesh or less in the junction of walls and floors.

Routinely inspect beams and storage areas for evidence of rat runways and nests.

If you find signs of rodents, call in a professional exterminator. Exercise extreme care so as not to contaminate fish or work surfaces with rodenticides.

(2) Water supply and waste disposal.

(*a*) *Water supply.*

Use only potable water for cleaning fish in any form or for cleaning any surface that could come in contact with food products or that could contribute to their contamination. Sea water may be used for the fluming of whole or dressed fish if the source meets local health requirements and if the water itself meets the microbiological requirements of the "Drinking Water Standards."

If water from public water supplies is used, test it against the "Drinking Water Standards" at least every 6 months to ensure that no in-plant contamination has occurred.

If water from a private well is used, make sure that the source is free of contamination. Test the water for purity monthly.

If chlorinators are required to ensure a continuous supply of potable water, use an automatic type equipped with warning devices to signal when it is not functioning properly.

Throughout the plant, provide both hot and cold water under adequate pressure and in quantities sufficient for all operating needs.

Install all equipment so that liquids will not be back syphoned into lines carrying potable water.

In general, except as provided above, do not use nonpotable waters in the plant. If such water is used for fire protection, steam lines, and the like, supply it in separate lines with no cross connections with pot-

able-water lines. Clearly mark nonpotable water lines and outlets, and instruct all plant personnel that nonpotable water is a deadly hazard if it comes in contact with food products.

(*b*) *Waste disposal.*

Ensure that waste-disposal systems meet the pertinent requirements given under the section on "Floor drains," page 66.

If permitted by local ordinances, discharge plant wastes into the municipal sewer system.

If you use a private septic tank or sewage disposal system, ensure that it is efficiently designed and operated so as not to produce objectionable conditions.

Do not discharge gurry and processing waste or plant sewage directly into harbors or other water areas without explicit written permission of Municipal or State Public Health Authorities.

Have any sewage-disposal facilities approved by the appropriate health authorities. Get the approval in writing, indicating when the facilities were inspected last.

Store gurry and other fish waste that cannot be carried by a sewage-disposal system in insectproof and rodentproof containers outside the plant or in physically segregated refrigerated rooms that are not used for any food products. Empty or remove unrefrigerated gurry from the plant premises at least once every 8 hours. If the containers are to be reused, wash and sanitize them before using them again. Do not store gurry in refrigerated rooms above freezing (32° F.) for more than 48 hours. Dispose of frozen gurry as expeditiously as possible, and do not keep it on the premises for more than a week.

(3) Refrigeration.

Make the refrigeration adequate to handle raw materials as will be discussed under the section on "Receiving raw materials," page 78.

Provide a temperature of 50° F. or less in work areas where fresh fish are processed.

Maintain freezer rooms at −10° F. or lower for the storage of the finished product.

For the initial freezing of finished products, use plate freezers or blast-freezing tunnels that provide contact temperatures of −20° F. or lower.

If refrigeration wall coils are used in chilling rooms, provide, beneath the coils, a drip gutter of concrete or other moisture-impervious material properly connected with the drainage system.

Provide overhead refrigeration coils or plates in chilling rooms with insulated drip pans connected to drains placed beneath.

Use potable water in making ice used for holding fresh fish or other food products. Store, transport, and handle the ice in a sanitary manner. Do

(3) Refrigeration—Continued.

not reuse ice after it has been in contact with fish or fish products or with contaminated work surfaces or holding areas.

(4) Lighting and ventilation.—Both proper light and ventilation are important in maintaining sanitary surroundings and comfortable employee working conditions.

(*a*) *Lighting.*

Provide unrefrigerated workrooms with direct natural light where possible. In windows and skylights, use uncolored glass having a high transmissibility of light.

Use heat-absorbing (blue) glass to reduce glare in windows and skylights that are exposed to considerable sunshine.

In a workroom, make the glass area at least one-fourth the size of the floor area.

Provide well-distributed artificial lighting of good quality where natural lighting is not available or sufficient. In work areas, make the overall intensity of artificial illumination not less than 20 foot-candles.

Lights over processing areas should be covered by clear shields to prevent glass from falling into the food products if a light bulb should break.

In candling for parasites, use lights that provide at least 50 foot-candles of illumination. Cover the light by a clean glass surface so arranged as to prevent any moisture from seeping down to the light fixture.

(*b*) *Ventilation.*

Provide sufficient natural or mechanical ventilation to control visible molds, objectionable odors, or excessive condensates.

Provide ventilation by means of windows, skylights, mechanical air conditioning, or a fan-and-duct system.

Supply mechanical ventilation in refrigerated workrooms where natural ventilation is lacking.

Locate fresh-air intakes so that the air is not contaminated with odor, dust, or smoke.

Where mechanical systems are used as the sole means of ventilating nonrefrigerated workrooms and employee welfare rooms, use systems that can provide at least six complete changes of air per hour.

Install the ventilation systems so that air does not move from raw material or preparation rooms into processing or packaging rooms.

b. Processing equipment.—Having considered the basic processing facilities, we shall now consider processing equipment. Design all equipment and utensils of such material and construction that they are smooth, easily cleanable, and durable, and that any surfaces in contact with the product are free from pits, cracks, and scale. In addition, design

and construct the equipment and utensils to prevent contamination of fish and fishery products with fuel, lubricants, metal, and other extraneous material.

(1) New equipment.—Ensure that new equipment conforms to the applicable standards cited in the AFDOUS Food Code (Association of Food and Drug Officials of the United States, 1962) and with any more recent revisions of these standards.

(2) Materials.

Use stainless steel as far as possible in all metal equipment that will come in contact with seafood.

In general, do not use galvanized metal, because it is not sufficiently resistant to the corrosive action of food products and cleaning compounds. If you must use galvanized metal for economic reasons, use it for such purposes as the construction of waste containers. If galvanized metal is used, make sure that it has the smoothness of high-quality commercial dip.

Where fish are handled, make cutting boards or table tops of synthetic rubber-thermoplastic or of other hard, nonporous, moisture-resistant, synthetic material. If you use hardwood cutting boards, be sure that the surfaces are smooth and intact.

Do not use copper, cadmium, lead, painted surfaces, enamelware, or porcelain on surfaces in contact with the product. (The first three materials are toxic, and the last three may chip or flake off into the product.)

Make certain that any plastic materials and resinous coatings that you use are abrasion- and heat-resistant, shatterproof, and nontoxic, and that they do not contain any material that will contaminate the fish or fishery products.

(3) Conveyor belts.—Make conveyor belts of moisture resistant material that is easy to clean, such as nylon, hard-finished rubber, or stainless steel.

(4) Equipment design.—Design the equipment in such a way as to eliminate dirt-catching corners and inaccessible areas. Install equipment capable of rapid and complete breakdown for cleaning. To facilitate cleaning, use steel tubing rather than angle or channel iron.

(5) Motors, bearings, and switches.

On food-handling equipment, locate all motors and oiled bearings in such a way as to prevent oil or grease from contacting the product.

Protect motors and switches from contact with water.

Raise motor mounts high enough to permit you to clean under them and between them.

Protect drivebelts and pulleys with guard shields that can be readily removed for cleaning.

(6) Welding.—Make all welding within the product area continuous, smooth, even, and as nearly flush with adjacent surfaces as possible.

(7) Stationary equipment.

Install all parts of stationary, or not readily movable, equipment at least 1 foot from walls and ceilings to provide access for cleaning.

Mount this type of equipment at least 1 foot above the floor, or else have a watertight seal with the floor.

(8) Water-wasting equipment.—Install water-wasting equipment--such as flumes, brining tanks, and wash tanks--in such a way that waste water from the equipment is delivered through an uninterrupted connection into the drainage system without flowing over the floor.

(9) Cutting tables.—Turn up the edges, at least 1 inch, of cutting tables or other equipment having water on the working surface.

2. Employee Facilities

Having considered the processing facilities, we now consider the facilities for the employees. To get plant personnel to recognize the importance of sanitary practices and to obtain their full cooperation, make proper provision for their personal needs. Considered here are the dressing rooms, toilet facilities, hand-washing units, and eating facilities.

a. Dressing rooms.

Provide separate dressing rooms for employees of each sex.

Separate the dressing rooms from the toilet and work areas.

Ventilate the dressing rooms, and provide receptacles for the disposal of cigarette stubs and other waste.

Provide each employee with a metal locker that is at least 15 by 18 by 60 inches. Place the lockers on legs 16 inches high to enable you to clean all areas of the floor.

b. Toilet facilities.

Separate toilet rooms from dressing rooms by tight, full-height walls or partitions.

Do not permit toilet rooms to open directly into food-processing areas; instead, separate them by a ventilated vestibule with two sets of self-closing doors.

Provide elongated water closets with open split seats, in the following ratios:

Persons employed	Toilets provided
Number	*Minimum number*
1 to 9	1
10 to 24	2
25 to 49	3
50 to 100	5
Each additional 30	1

c. Hand-washing units.

Locate hand-washing unit (lavatory) conveniently and make sure that they meet the appropriate requirements discussed under the section on "Plant sanitation and cleaning provisions," page 75.

Make the minimum size of bowl 16 by 16 by 9 inches, and supply each lavatory with hot and cold water delivered through a mixing faucet fixed at least 12 inches above the rim of the bowl so that an employee may wash his arms.

Locate liquid soap and sanitary towels in suitable containers at each wash basin.

d. Eating facilities.

Provide clean, well-lighted, and ventilated eating facilities that are separate from work areas and toilet areas.

If eating facilities are provided in the dressing room, set the space aside separate from the immediate locker area.

Provide tables and chairs or benches, washing facilities, and drinking fountains.

Clean the area after regularly scheduled work breaks and lunch periods to prevent food particles from attracting vermin and insects.

II. PROCESSING RECOMMENDATIONS

We now have given detailed consideration to the guidelines on the plant--both its premises and its construction, including the processing facilities and the employee facilities. We turn next to the guidelines on the processing itself. In so doing, we consider methods of guarding against microbial contamination of the plant and product and then give attention to the handling of the product.

A. GUARDING AGAINST MICROBIAL CONTAMINATION

In guarding against microbial contamination, we are aided by a knowledge of certain procedures for testing for the presence of microbial contamination and of sanitation principles involved in microbial control.

1. Bacteriological Testing Procedures

Have the microbiological tests listed below (under "Microbial tests to be performed") made periodically on samples of the finished products from all processing lines. These tests will serve as a guide in determining whether you have a sanitation problem in your plant. Do not consider the numbers as being an absolute standard of product quality, but rather as being levels that, if exceeded, indicate that a more thorough microbiological survey of raw material, processing equipment, and personnel should be made. This survey will help you decide whether you do have an area that is a source of serious contamination or that could become one.

Here we are concerned specifically with five subjects:

a. Directions for microbial tests.

b. Microbial tests to be performed.

c. Sampling.

d. Corrective action.

e. Resurvey.

a. **Directions for microbial tests.**—Have the microbiological tests carried out according to the procedures given in "Standard Methods for the Examination of Dairy Products": current edition, prepared by the American Public Health Association (1967). These procedures are suggested for fishery products but are not standardized for such products. There are still no generally recognized methods for testing fishery products, but the procedures given in Standard Methods for Dairy Products will prove generally satisfactory for the type of microbiological survey recommended in this section.

b. **Microbiological tests to be performed.**—The microbial tests to be performed include the following: (1) total plate count, (2) coliforms, (3) Salmonella, (4) E. coli, and (5) coagulase positive staphylococcus.

(1) Total plate count.—Take remedial action if the total plate count exceeds 200,000 organisms per gram. Consider that the total plate count indicates the entire bacterial exposure of the product. Furthermore, consider that it also indicates the level of spoilage organisms present. Although a direct relation between total plate counts and organoleptic quality or storage life has not been established, excessive counts do indicate that the storage life of fresh fish with such counts will be reduced materially.

(2) Coliforms.—Take immediate remedial action if the MPN (most probable number) is more than 360 per gram. The presence of coliform organisms indicates contact of the product with water and soil contaminants and warns that the product may possibly be polluted with sewage.

(3) Salmonella.—Take immediate remedial action if the sample is not free of this organism. Salmonella is a bacteria that causes food poisoning. The presence of this organism indicates human or animal contamination.

(4) E. coli.—Take immediate remedial action if the MPN is greater than 50 per gram. This organism is one of the coliform group and is a specific indicator of fecal contamination. Although this organism does not cause disease, it indicates that the product probably has been contaminated with organisms that are pathogenic.

(5) Coagulase positive staphylococcus.—Take immediate remedial action if the MPN is more than 5 per gram. The test for this organism should be the confirmed test. The presence of the organism indicates human, infectious contamination. It is a toxin-producing organism that causes food poisoning. The organism is readily killed by heat, but the toxin is quite heat stable.

c. **Sampling.**

Make the initial survey of the finished fresh or frozen product at the point where it is ready to leave the plant.

Sample precooked products before they enter the cooker. Cooking will destroy many organisms but not all toxins; for this reason, microbial tests on cooked products give a misleading indication of their microbial exposure.

Take samples separately and place them in sterile containers.

Store fresh samples at 33° F.

Store frozen samples at 0° F. or lower.

Test all samples as soon as possible after they are taken.

If the results of any of the bacteriological tests exceed the suggested limits, make a complete microbiological survey of the plant.

Take samples of all raw material.

Take samples of the product after each stage of processing (that is, after initial washing, filleting, skinning, brining, tempering, and cutting of frozen blocks; after applying batter and breading; and after packing).

Take swabs of all equipment during processing and after cleaning up.

d. Corrective action.—From the results of the complete survey, take corrective action if any trouble spots were identified. Corrective action may range from a general cleanup of the entire plant to something as specific as cleaning up a single piece of equipment, discarding certain raw material, or having one of the employees change his personal habits.

e. Resurvey. — To determine the effectiveness of the corrective action, repeat the product survey after the corrective sanitizing and cleanup measure have been instituted. Make periodic surveys to determine if the plant-sanitation program is continuing to be effective or if new problems in sanitation have developed.

2. Plant and Personnel Sanitation

Having outlined the bacteriological testing procedures, we now consider plant and personnel sanitation. In so doing, we consider provisions relating to plant sanitation and cleaning and those relating to personnel practices.

a. Plant sanitation and cleaning provisions.—Keep in mind that, although proper sanitation is the direct responsibility of the plant manager, an effective sanitation program can be obtained only when every employee in the plant is instructed in proper sanitary precautions and is fully impressed with the reason for proper sanitation in terms of product quality and protection of the product from public-health hazards.

Plant sanitation requires the services of a sanitarian and adequate cleaning methods and facilities.

(1) Sanitarian.—Assign one person as a sanitarian for the plant. The sanitarian must be tactful and have good judgement. If the plant is large, assign one or more assistant sanitarians for specific work areas. Make the sanitarian responsible for supervision of all plant-cleaning operations. Have him thororoughly inspect all processing areas and equipment before each day's operation, and see that any deficiencies are corrected before operations are started.

(2) Cleaning and cleaning facilities.

(*a*) *Cleaning.*—To clean adequately, adopt a schedule and carry out the cleaning steps in proper sequence.

[1] Cleaning schedule.

Adopt a cleaning schedule for each area in the plant, and adhere to it unless conditions warrant more frequent cleaning or sanitizing

[1] Cleaning schedule—Continued

operations. Thoroughly clean continuous-use equipment such as conveyors, filleting machines, flumes, batter and breading machines, cookers, and tunnel freezers at the end of each working shift, or oftener, if conditions indicate the need.

Clean batter machines and other equipment in contact with milk or egg products more frequently, depending on the temperature at which the batter is maintained, the type of material going into the batter (fresh or frozen), the ambient temperature of the work area, and the microbiological level of the raw materials and fish. Ascertain these factors, and design the cleaning schedule accordingly.

Clean and sanitize portable equipment and utensils after they are used, and store them above the floor in a clean, dry location so that they are protected from splash water, dust, and other contaminants.

[2] Cleaning sequence.

Mechanically or manually remove loose dirt by scraping and brushing floors and equipment.

Rinse with cold or warm water. Because fish residues and other proteins coagulate at high temperature and may become baked onto the contact surface, remove these materials at temperatures below 100° F. early in the cleaning process.

Wash with an acceptable detergent.

Rinse twice with hot water at a temperature of at least 170° F. Hot water is more effective than cold water in removing fats, oils, and inorganic material.

Sanitize with an acceptable bactericidal agent. Chlorine compounds are the most widely used--recommended strengths are given later. Other sanitizing agents approved for use in food-processing plants are also effective.

Rinse twice with hot water. A thorough rinse with potable water should follow any operation involving a chemical sanitizing agent.

(*b*) *Cleaning facilities.*—Here are considered detergents, chlorine solutions, single-service articles, and hand-sanitizing units.

[1] Detergents.—In using detergents, we are concerned about their characteristics and about which of them are approved for use with food products.

[a] Characteristics of detergents.

Keep in mind that the desirability of a detergent usually is determined by the degree to which it exhibits the following characteristics (Somers, 1949).

High wetting or penetrating action, which causes rapid washing away of the soil.

Good rinsibility, which results in the detergent and soil being rinsed from the equipment freely and rapidly after the desired cleaning has been accomplished.

High emulsifying power for oils.

High deflocculating or dispersing power, to bring deposits of precipitates into suspension so that they can be washed away.

Water conditioning or sequestering properties in alkaline solutions, to prevent deposits on equipment of any calcium and magnesium compounds from the water.

Dissolving and neutralizing power, for the purpose of dissolving or neutralizing tenacious deposits and saponifying fats to make them soluble in water.

Low corrosiveness to the surfaces on which they are used.

[b] Approved compounds.—Detergents and sanitizing compounds approved for use in food processing plants may be found in the current edition of "List of Chemical Compounds - Authorized for Use under USDA Poultry, Meat, Rabbit, and Egg Products Inspection Programs," U.S. Department of Agriculture (1968).

[2] Chlorine solutions.

Use the following suggested concentrations of chlorine solutions in fish processing plants:

Use	Available chlorine
	Parts per million
Wash water	2 to 10
Rinse water on hands	100
Clean smooth surfaces (wash basin, urinals, glassware)	50 to 300
Clean smooth wood, metal, or synthetic surfaces (new boxes, new table tops, conveyor belts, machines)	300 to 500
Rough surfaces (worn tables, old boxes, concrete floors, and walls)	1,000 to 5,000

Keep in mind that it is important to rinse with clear potable water after using any sanitizing agent and that, to prevent corrosion, it is especially important to rinse metal surfaces after chlorine solutions are used.

[3] Single-service articles.

Store materials intended for one-time use, such as paper cups or towels, in closed containers, and dispense them singly and in such a manner as to prevent their being contaminated.

Provide closed containers for the disposal of such articles.

[4] Hand-sanitizing units.

Locate wash sinks and sanitizing hand dips outside of lavatories and adjacent to work areas, such as filleting lines or packing tables, where fish are handled.

Supply sanitizing dips with 100 parts per million available chlorine. Keep filleting knives and steels in sanitizing solutions when not in use, and have each filleter rinse his hands and change knives frequently.

b. Personnel provisions.—Employee health and employee practices are important in controlling microbial contamination.

(1) Employee health.

Have all food-handling employees examined physically prior to their starting work at the plant and at least annually thereafter. Comply with local health requirements regarding the physical examination and see that each employee has a current and valid health certificate showing no evidence of any communicable disease. Have the employee take a physical examination before returning to work after any contagious illness.

Do not allow employees with open sores and lesions into food-processing areas.

(2) Employee practices.

Prohibit employees from eating, using tobacco in any form, and spitting in food-handling areas.

Do not allow employees to wear jewelry, except plain wedding bands and unadorned pierced earrings (not screw-on type), in food areas.

Have all food handlers wear clean outer garments, preferably white, that cover personal clothing. Have fish filleters wear easily cleanable rubber or plastic aprons or coveralls and boots. Such garb should be worn by personnel working with fresh fish or on cleanup crews using large amounts of water. Require that all clothing worn during working hours be clean, and maintain an adequate supply of replacement garments.

Have all employees wear clean head coverings (caps or hairnets) that cover or hold the hair in place.

Require that each employee wash and sanitize his hands after each absence from a work station. When rubber gloves are worn, have them washed and sanitized in the same manner.

B. PRODUCT HANDLING

In our guidelines on processing, we now have completed our suggestions for guarding against microbial contamination. We turn now to our guidelines on how to handle the product. Here, we consider the receiving of the raw material and the processing of it.

1. Receiving Raw Materials

By raw materials, we mean both the fish and any other raw materials used in processing.

a. **Fish.**—We consider first the fresh fish and then the frozen fishery products.

(1) Fresh fish.

Check fresh fish for signs of spoilage, off odors, and damage upon their arrival at your plant. Discard any spoiled fish.

If the fish are to be scaled, scale them before you wash them.

Unload the fish immediately into a washing tank. Use potable, nonrecirculated water containing 20 parts per million of available chlorine and chill to 40° F. or lower. Spray wash the fish with chlorinated water after taking them from the wash tank.

If incoming fresh fish cannot be processed immediately, inspect them, cull out the spoiled fish, and re-ice the acceptable fish in clean boxes; then store them preferably in a cold room at 32° to 40° F. or, at least, in an area protected from the sun and weather and from insects and vermin.

Wash, rinse, and steam-clean carts, boxes, barrels, and trucks used to transport the fresh fish to the plant if any of these are to be used again. If disposable-type containers are used, rinse them off and store them in a screened area until you remove them from the premises.

(2) Frozen fishery products.

Use a loading zone that provides direct access to a refrigerated room.

Check the temperature of the product at several areas in the load. When the product arrives, it should be 0° F. or lower.

Place the product on pallets and assign a freezer lot number to it to ensure that the rule of "first-in, first-out" is observed.

Keep the freezer storage at −10° F. or lower, and use a separate blast freezer capable of rapidly lowering to −20° F. any product that arrives at a temperature higher than 0° F.

b. **Other raw material (dry).**

Unload other raw material in an area separate from the fresh or frozen products.

Store the material in a dry, ventilated area on pallets or shelves that will keep the material away from the floors and the walls.

Screen the storage area adequately to prevent entrance of insects during loading or unloading operations.

2. Processing Raw Material

Keep in mind that fish is a highly perishable food. The primary cause of deterioration of fish flesh and the resulting loss of quality is bacterial contamination. Every step in the recommendations for sanitary plant operation and fish-handling procedures is designed to reduce this contamination and thereby protect the health of the consumer and maintain the quality of the product. The basic rules for handling a fishery product are:

Keep the product cool, as near 32° F. as possible for fresh fish and below 0° F. for frozen fish.

2. Processing raw material—Continued

Keep it clean.

Keep it moving. It is the combination of time and temperature that permits bacteria to grow and build up. Even under optimum conditions, quality will be lost, so you should get the product into the consumer's hands as rapidly as possible.

a. Fresh fish.

Handle incoming fresh fish as was described in the section on "Receiving raw materials," page 78.

Cool the filleting room to 50° F. or lower. If the room is not cooled, then ice the fish so as to maintain their internal temperature of 40° F. or lower.

During hand-filleting operations, scrub the filleting boards at least twice a day. Use water containing 2 to 5 parts per million available chlorine to flush continuously the filleting boards and conveyors used to transport whole fish.

When cutting fillets by hand, handle them so that the cut surface does not come in contact with the filleting board; then immediately place them on a fillet conveyor or in a container.

Furnish filleting machines with a continuous supply of water on the surfaces in contact with the fish.

Have the fillets discharged directly onto a conveyor into a container.

Use a machine to prepare skinless fillets and spray water on the skinning machinery.

Complete all trimming operations before sending the fillets to the final wash.

Because certain species of fish (such as cod, ocean perch, and some Pacific rockfish) may contain parasites, candle the fillets from these fish before brining them in the final wash. Do the candling on a clean glass surface well illuminated from below. Because heat from the lights may cause bacteria to grow rapidly on the surface of the candling table, clean the surface thoroughly and sanitize it frequently. Continuously flush it with chlorinated water.

A brining tank, to be effective, must be used correctly. Use brine as a final wash in order to help reduce the loss of moisture. Chill the brine to 35° F. or lower, chlorinate it, and change it at least once an hour, so that it will decrease bacterial contamination. Convey the fillets through the tank so as to regulate their time of exposure to the brine; after they leave the tank, pass them through a multijet mist spray. Keep in mind that the strength of brine and exposure time should depend on the species of fish being handled. Only mildly brine the fillets of fatty fish, especially those fillets that are to be frozen; otherwise, the residual salt on the fillets will accelerate the development of rancidity during storage.

See that fresh fillets that are to be packed in bulk have an internal temperature no higher than 35° F. before the fillets are packed in a bulk container. If need be, use an adequately refrigerated brining tank as a prechiller. Promptly pack and ice well the prechilled fillets, or place them in a cold-storage room at 30° to 35° F.

Promptly pack fillets that are to be frozen, and place them in a freezer in less than 30 minutes after they are packed. If it be necessary to transport the fillets to another building for freezing, transport them under refrigerated conditions if the

elapsed time from packing to entering the freezer exceeds 30 minutes. Do not expose the packaged fillets to sun and dirt.

b. Frozen fishery products.

Handle incoming frozen fish as was described in the section on "Receiving raw materials," page 78.

Where frozen fishery products such as fish blocks must be tempered (brought up to a higher temperature) before being processed, temper them in a refrigerated room under controlled conditions. (Uncontrolled tempering in work areas causes blocks on the outside of the load to become excessively warm while the blocks at the center of the load remain too cold for efficient processing.) Once the blocks are tempered to the desired temperature (not higher than 20° F.), process them as soon as possible. Slake out, in refrigerated water, blocks or bulk packs of fillets or whole fish that must be thawed and separated for further processing. Prechill the water to below 40° F. Remove the fish or fillets as soon as they are thawed sufficiently to be processed. Change the water and clean and sanitize the tanks before you put more fish in them.

Good product handling practices require that breading lines be given particular attention. Maintain the temperature of the batter below 50° F. Discard all unused batter at the meal break and at the end of each work shift, and clean and sanitize the batter container before reloading it. Discard unused breading at the end of each work shift. Place drip pans and dust shields around breading and batter machines. Remove any spillage from the floors at once.

When processing precooked products, pass cooking oil through a continuous filter to remove any food particles in the oil. Locate adequate exhaust fans in the working areas to remove smoke, odors, and excess heat. Pass precooked products directly from the cooker to a freezer before packing them. Maintain temperature-control charts for all cookers.

Handle all frozen products as expeditiously as possible to prevent them from thawing. Do not allow the time between bringing the frozen blocks to the processing area and placing the finished product in the freezer to exceed 1 hour. (In a well laid-out plant, this time will be less than 30 minutes.) Because of this short time interval, the work area need not be refrigerated, but prevent it from becoming warmer than 75° F.

Show the date of packing on the primary code containers of all finished products.

LITERATURE CITED

American Public Health Association.
1967. Standard methods for the examination of dairy products: Twelfth edition. American Public Health Association Inc., New York, N.Y.

Association of Food and Drug Officials of the United States.
1962. AFDOUS food code. J. Assn. Food Drug Off. 26(1): 30-36.

Somers, Ira I.
1949. How to select detergents for food plant. Food Ind. 21(3): 72.

Thompson, Mary H., and Robert N. Farragut.
1969. Problem of "green" frozen raw breaded shrimp. U.S. Fish Wild. Serv., Fish. Ind. Res. 5: 1-10.

U.S. Department of Agriculture.
1968. List of chemical compounds - authorized for use under USDA poultry, meat, rabbit, and egg products inspection programs. U.S. Department of Agriculture, Consumer and Marketing Service, Technical Services Division, Washington, D.C., (Revised Oct. 1968).

U.S. Public Health Service.
1963. Public Health Service drinking water standards, 1962. U.S. Pub. Health Serv. Publ. 956.

MS. 1968

TOW-BAR SYSTEM FOR SEINING FARM PONDS

by

Kenneth L. Coon and James E. Ellis

ABSTRACT

The farm-pond fish-raising industry has needed mechanized methods to lower the cost of harvesting the fish. This report describes equipment and its operation for hauling a small seine with farm tractors or trucks if the pond has levees or a shore that can accommodate these vehicles. The equipment works well with ponds up to 450 feet wide and of any length.

INTRODUCTION

Gordon (1965) and Coon, Larsen, and Ellis (1968) of the Bureau of Commercial Fisheries have developed and described mechanized seining equipment and techniques for use in lakes and large ponds. Prior to this mechanization, the fish farmer was restricted to using harvesting methods that involved the draining of a pond, the use of a large crew of men, and usually a considerable amount of time to seine even the smallest of ponds.

The critical need for mechanization in the farm-pond fish-producing industry has now led us to develop tow bars for hauling seines with standard farm equipment under certain fish-harvesting conditions. By means of tow bars attached to tractors or trucks, two men can harvest fish from ponds up to 450 feet wide and of any length, providing the levees or shore can accommodate the vehicles (Figures 1 and 2). The tow bars are simple to make and are relatively inexpensive. They cost about $200 for two bars plus $65 for an added seine reel.

Described here are the equipment needed and the method of operating it.

I. EQUIPMENT

The seine tow bar has three sections—one length of square steel tube and two sections of round iron pipe (Figure 3). The square tube is attached to a three-point tractor hitch or to a truck bumper by means of mounting brackets. This tube is 3½ inches square by 7 feet long and is made of ¼-inch-thick steel plate (American Society for Testing Materials Alloy 1025, or the equivalent). The square tube extends 2 to 3 feet beyond one side of the vehicle and is connected to the first section of pipe by a self-aligning bearing pivot joint. The first section of pipe is 3-inch inside diameter (iron-pipe standard) and 6 feet long. The second section of pipe is 2½-inch inside diameter and also 6 feet long. The pipe of smaller diameter slides into the one of larger diameter to provide for varying the length of

Authors: Kenneth L. Coon now *Commercial Catfish Culturist*, P.O. Box 476, Tuckerman, Arkansas 72743, and James E. Ellis, *Fishery Biologist*, Bureau of Commercial Fisheries Exploratory Fishing and Gear Research Base, 5 Research Drive, Ann Arbor, Michigan 48103.
Published April 1970.

Figure 1.–Tractor-mounted tow bar attached to a seine in a commercial catfish pond.

Figure 2.–Tractor mounted tow bar (with net reel) attached to a seine in a commercial catfish pond.

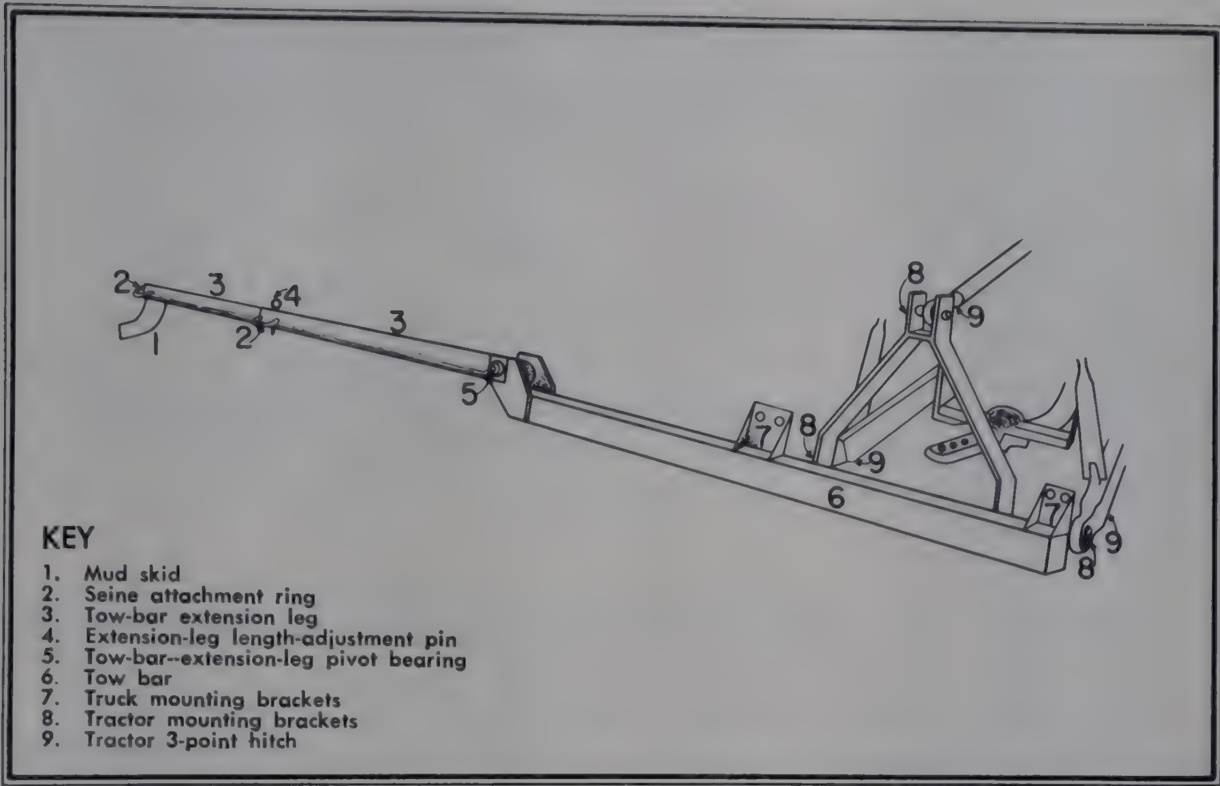


Figure 3.–Tow bar for pulling seines to harvest fish in certain farm ponds.

the tow bar 6 to 10 feet beyond the pivot. A pin through matching holes in the overlapping portion of the pipes keeps the pipes at the length wanted. Rings for attaching the seine are welded to the outer end of each pipe, and a ¼-inch, by 6-inch, by 18-inch curved mud skid is welded to the outer end of the pipe having the smaller diameter.

Additional convenience and efficiency can be gained by adding a net reel to one of the tow-bar units (Figure 4). The 8-foot-long

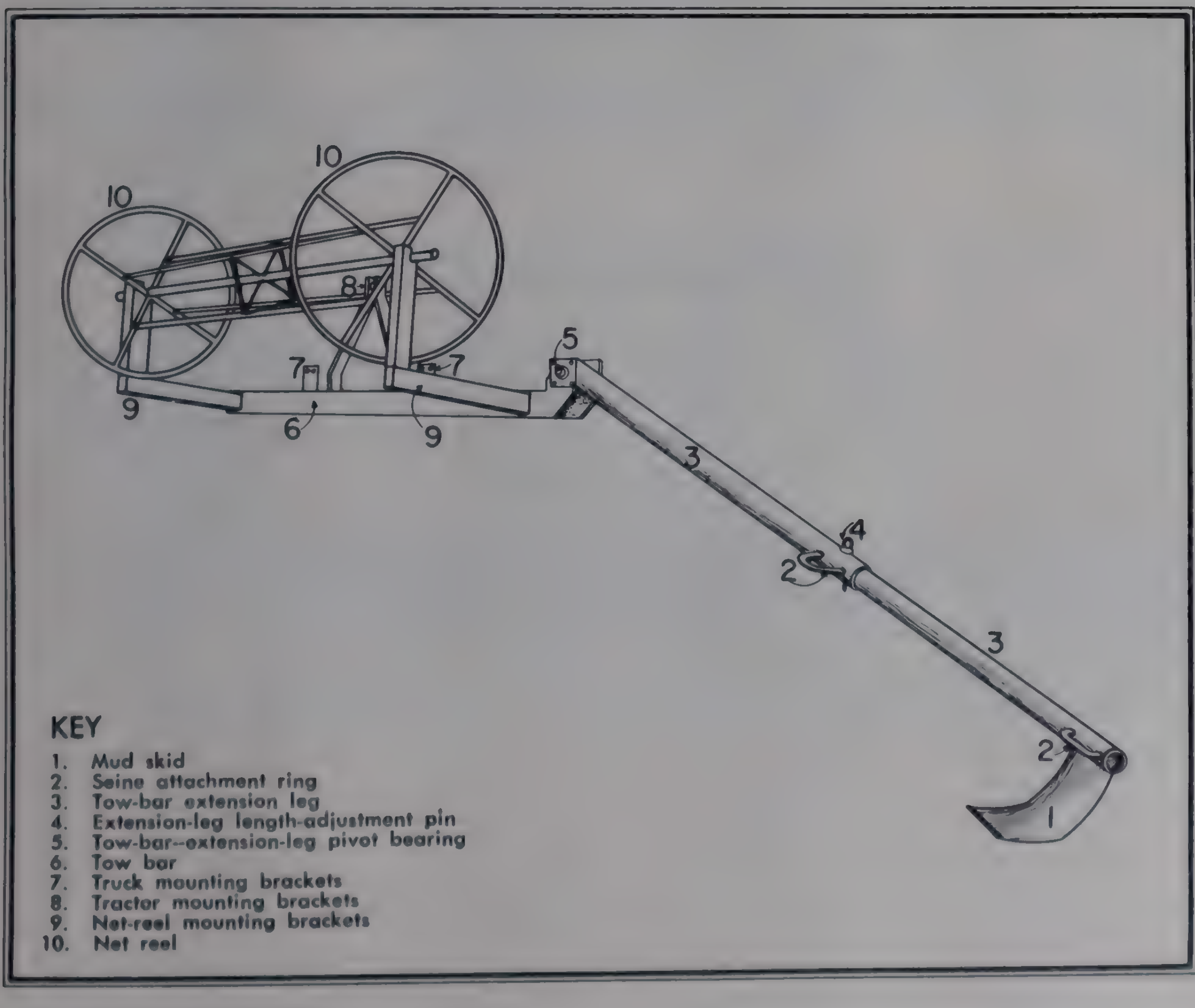


Figure 4.–Farm-pond-seine tow bar fitted with a net reel for stowing, transporting, and setting the seine.

net reel tested by the Bureau of Commercial Fisheries has core bars spaced 16 inches apart, has end flanges 32 inches in diameter, and has an axle that is 10 feet long. This reel, which will hold a seine of up to 500 feet in length, is of $\frac{3}{4}$-inch inside diameter pipe (iron-pipe standard). The square-steel-tube section behind the vehicle has to be $9\frac{5}{6}$ feet long to accommodate a reel 8 feet long. Support brackets for the reel are 3-inch square tubes made of $\frac{1}{4}$-inch-thick steel plate (American Society for Testing Materials Alloy 1025, or the equivalent) and are welded to the square-tube section of the tow bar. The horizontal legs of the brackets are 18 inches long and, on their outer ends, have 15-inch-long vertical legs welded upright. Semicircular cuts, in the top end of the upright legs, accommodate 3-inch-long sections of half-round, 2-inch inside-diameter pipe used as friction bearings for the $1\frac{1}{2}$-inch inside-diameter pipe axle of the reel. A removable crank handle at one end of the axle facilitates your turning the reel as you wind in the seine.

II. METHOD OF SEINING WITH TOW BARS

Two vehicles, with a tow bar attached to each, are positioned back-to-back at one corner of the pond. The vehicle with the seine reel lays the net along the end of the pond while the other vehicle anchors one end of the net (Figure 5).

The self-aligning bearing pivot permits the skid on the tip of the tow bar to rest on the ground regardless of how the levee slopes or of how irregular the levee is. The tip of the tow bar does not need to be exactly at the edge of the water. It operates satisfactorily at any location from a few feet into the water to a few feet up on the bank.

After the net has been laid along the end of the pond, the two vehicles proceed along the opposite levees at a rate of up to 50 feet per minute.

The vehicles must meet near the site where you intend to remove the fish whether it be at a corner of the pond or at someplace in between the two levees. To get at the fish, you can dry them up either by hand or by attaching both ends of the net to one of the vehicles and slowly pulling it up onto the shore.

In actual tests, the equipment illustrated in Figures 1 and 2 worked well.

SUMMARY AND CONCLUSIONS

A simple, relatively inexpensive, tractor or truck tow-bar system was developed and tested to remove farm-cultured fish from ponds up to 450 feet wide and of any length.

The advantages of the system over manual methods include: (1) when the system is used, draining the pond is unnecessary, (2) seining is more convenient and faster, and (3) increasing the efficiency in this manner reduces the cost per acre of water seined and per pound of fish handled.

The main limiting factor is the adequacy of the levees or shore of the pond to accommodate the tractors or trucks.

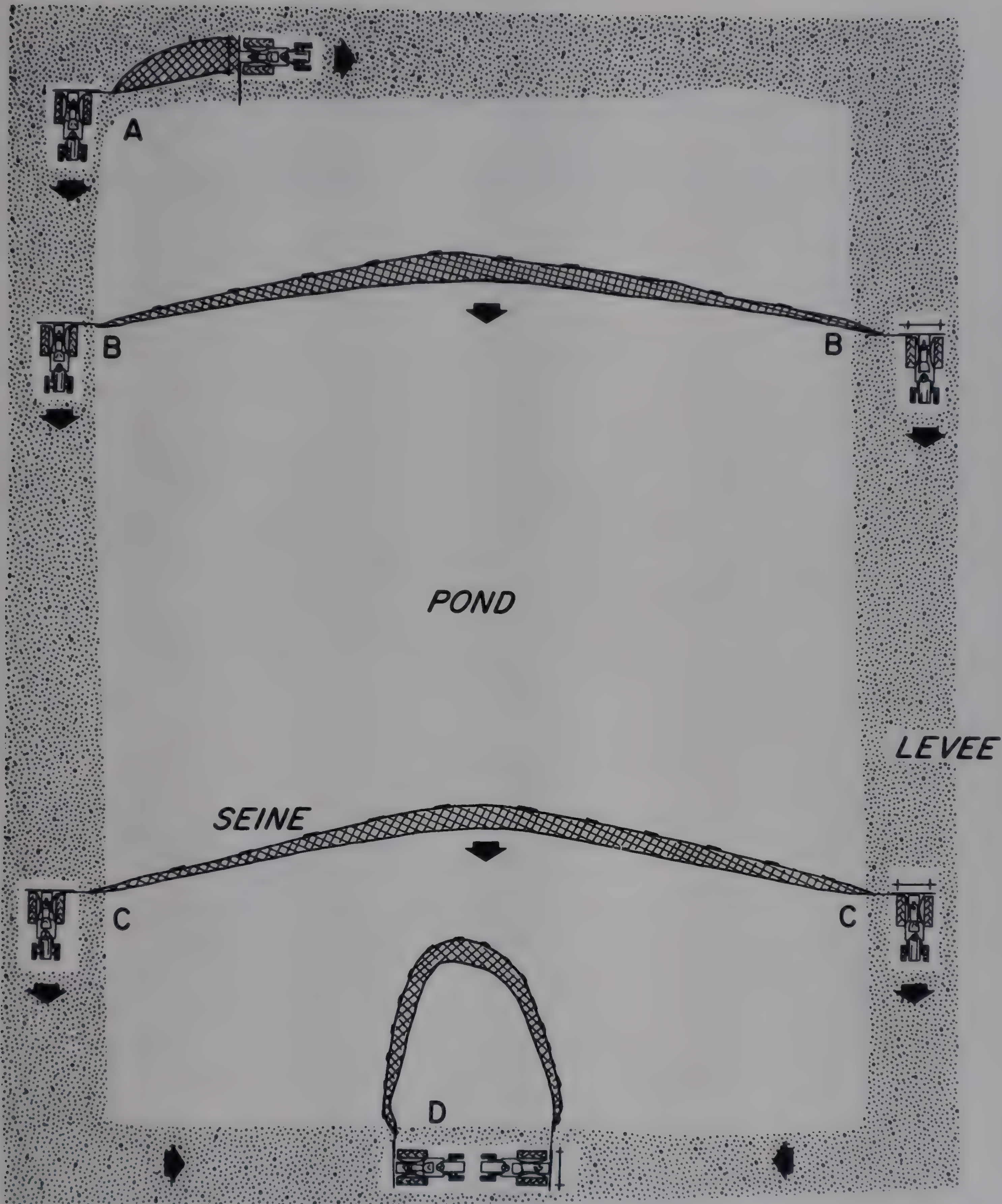


Figure 5.—Major steps in operating a farm-pond seine with tractor-mounted tow bars. A—setting the seine. B and C—pulling the seine. D—pocketing the fish at the site of removal.

LITERATURE CITED

Gordon, William G.
1965. Haul seining in the Great Lakes. U.S. Fish Wildl. Serv., Fish. Leafl. 577, 15 pp.

Coon, Kenneth L., Alfred Larsen, and James E. Ellis.
1968. A mechanized haul seine for use in farm ponds. U.S. Fish Wildl. Serv., Fish. Ind. Res. 4: 91-108.

MS. #2022

PRELIMINARY STUDY OF THE PROXIMATE COMPOSITION OF MEAT OF FUR SEAL, *Callorhinus ursinus*

by

Richard W. Nelson and Harold J. Barnett

ABSTRACT

Finding profitable uses for the carcasses of fur seal has presented a problem to the Bureau of Commercial Fisheries. As a part of an effort to encourage use of the carcasses, several separate lots of meat and ground eviscerated carcasses were analyzed to determine proximate chemical composition. In this preliminary study, individual carcasses and samples from lots of ground carcasses were high in protein content and variable in oil content. Analyses of small samples of male and female seals taken at different times during the harvesting season indicated that variation in composition did not correlate with the time of sampling nor with the sex of the animal.

CONTENTS

INTRODUCTION

Fur seals harvested annually on the Pribilof Islands in the Bering Sea provide the world's largest source of sealskin furs. This harvest is administered by the Bureau of Commercial Fisheries. During 1956 through 1963, the Bureau took an annual average of 81,600 sealskins[1] from St. Paul and St. George Islands, the two largest islands in the Pribilofs.

[1] Personal communication from the Bureau of Commercial Fisheries Marine Mammal Biological Laboratory, Seattle, Washington.

Authors: Richard W. Nelson, *Research Chemical Engineer*, and Harold J. Barnett, *Research Chemist*, Bureau of Commercial Fisheries Technological Laboratory, 2725 Montlake Boulevard East, Seattle, Washington 98102.

Published April 1970.

On St. Paul Island, the carcasses that remained after being skinned were formerly processed into meal and oil in a reduction plant located on the island. However, after 1961, the reduction plant was not operated, owing to the low market prices for meal and oil.

The Bureau therefore investigated other methods of using the carcasses to prevent waste of the more than 2 million pounds available and to get income from them. The most promising result of efforts to use the carcasses has been the production of ground meat for mink feed. The carcasses are purchased by private contractors and are processed into a ground, frozen product in a plant located on St. Paul Island.

During the period of investigation into the possibilities of using the seal meat for mink food, the Bureau of Commercial Fisheries Technological Laboratory at Seattle analyzed several different small lots of fur-seal samples to determine their proximate chemical composition. The purpose of this paper is to report on the analyses made in this limited study.

For the analyses, samples of carcasses and meat were obtained from several sources during the years 1962 and 1963. The samples were from (I) eviscerated carcasses and (II) commercially ground seal meat.

I. EVISCERATED CARCASSES

One lot of eight, frozen, eviscerated seals was obtained in 1962 from St. Paul Island, and the heads and flippers were removed. Each carcass in this lot was analyzed separately. Six of these carcasses were ground entirely, so the ground samples contained blubber and bone. The remaining two were trimmed of blubber and bone, and only the meat was analayzed.

A. SAMPLES CONTAINING BLUBBER AND BONE

1. Procedure

During the 1963 killing season, the staff on St. Paul Island prepared and froze six carcasses from each week's harvest and held them in frozen storage on the island until they could be shipped to Seattle. Samples were taken between July 11 and August 29. The collection of samples conformed to the normal pattern of killing, which consists of taking only males during the early part of the season and taking only females during the latter part of the season.

Carcasses to be analyzed were sawed into sections about 2 inches thick and then were allowed to thaw slightly to facilitate their being ground. A 25-horsepower Autio grinder equipped with a ½-inch grinding plate was used for grinding.[2]

Representative portions from each sample were reground in a Hobart food cutter to reduce the size of the particles of meat further. The samples were packed in metal cans and stored at −20° F. until needed for analysis.

Each sample was analyzed, in duplicate, for moisture, protein, oil, and ash by the use of standard procedures (Horwitz, 1955).

2. Results

Analyses of individual carcasses (Table 1) show that the concentration of oil varied con-

Table 1.—Proximate composition of six individual eviscerated carcasses of fur seal

Sample	Proximate composition			
	Moisture	Oil	Protein	Ash
	Percent	*Percent*	*Percent*	*Percent*
Carcass 1	61.9	17.4	18.5	3.0
Carcass 2	61.4	15.3	19.9	3.7
Carcass 3	63.7	12.8	20.2	4.2
Carcass 4	66.4	8.7	21.2	4.2
Carcass 5	64.0	12.6	20.1	4.8
Carcass 6	62.1	12.9	19.9	5.5
Average	63.2	13.3	20.0	4.2

Note: The carcasses included bones and some blubber but did not include heads, viscera, hides, or flippers.

[2] Use of trade names is only to facilitate descriptions; no endorsement is implied.

siderably from one carcass to another. This variation may be due to inherent differences between animals or, more likely, may be due to the fact that different amounts of blubber, or fat, were left on the carcass during skinning.

B. SAMPLES WITH BLUBBER AND BONE REMOVED

A comparison of the data on oil concentration in Table 2 with those in Table 1 shows the effect of blubber. Where the whole carcass was ground, with the blubber left on the carcass, the average concentration of oil in the meat was 13 percent, whereas with the blubber removed from the carcass, the concentration of oil in the meat was only 3 percent.

Table 2.—Proximate composition of fur seal (meat only)

Sample	Proximate composition			
	Moisture	Oil	Protein	Ash
	Percent	*Percent*	*Percent*	*Percent*
Carcass 7	71.7	3.7	24.6	1.4
Carcass 8	72.7	2.7	24.6	1.3
Average	72.2	3.2	24.6	1.3

Note: The samples were prepared from blubber-free, lean meat trimmed from the whole carcass and then blended in a laboratory grinder.

A comparison of the data on ash content in the two tables shows the effect of bone. Where the whole carcass was ground, with the bone left in, the average concentration of ash was 4.2 percent, whereas with the bone removed, the concentration of ash was only 1.3 percent.

C. SAMPLES OBTAINED AT INTERVALS DURING HARVEST SEASON

Samples of carcasses taken at various times during the 1963 killing season were analyzed to determine whether significant changes in composition occur as the killing season progresses. During this season, which coincides with the mating season, the harem bulls establish their territory, the female seals (mated from previous year) have pups, and mating takes place. The feeding habits are abnormal during this period. Samples of male and female carcasses, taken over the span of the entire killing season, were analyzed to determine whether composition changes during this period. Twenty-four carcasses were examined. Six males were obtained on July 11; another six, on August 1. Six females were obtained on August 15; another six, on August 29.

The results (Table 3) from this small sample do not indicate any marked differences in composition due to season or sex. These samples were all lower in concentration of moisture than were those analyzed previously. This difference in moisture concentration (compare with the average of six carcasses in Table 1) may be due to a loss of moisture during frozen storage.

Table 3.—Proximate composition of male and female eviscerated fur-seal carcasses, period from July 11, 1963, to August 29, 1963

Sample description			Proximate composition			
Date taken	Sex of seal	Carcasses in sample	Moisture	Oil	Protein	Ash
		Number	*Percent*	*Percent*	*Percent*	*Percent*
7-11	Male	6	61.0	12.9	23.0	3.9
8- 1	Male	6	61.6	12.6	23.3	4.7
8-15	Female	6	62.1	9.1	23.7	5.2
8-29	Female	6	60.5	12.5	23.5	5.0

Note: The carcasses included bones, flippers, and some blubber but did not include heads, viscera, or hides. All carcasses were frozen in burlap bags on St. Paul Island. Each sample lot analyzed consisted of the six carcasses combined to form a single sample.

II. COMMERCIALLY GROUND SEAL MEAT

A. PROCEDURE

Samples of ground carcass meat were obtained during a trial grinding and freezing operation by a firm in Vancouver, British Columbia. The lot sampled was part of a commercial experiment in which carcasses were shipped from St. Paul to Vancouver, iced in the hold of a fishing vessel (*Mina C.*). The product was used for ranch mink feed. About 150 tons of carcasses that had been held from 12 to 18 days on ice at the time of arrival in Vancouver were used in the trial.

The carcasses were unloaded from the vessel and ground in an Autio grinder using a

½-inch grinding plate. Three samples were obtained from the material as it was discharged from the grinder, and each sample consisted of about 12 aliquots taken at random and combined to form 5-pound portions. The samples were stored at −20° F. at the laboratory. At the time that the samples were prepared for chemical analyses, each portion was reground in a Hobart food cutter to reduce the size of the particles of meat.

B. RESULTS

The average concentration of oil in this large composite of ground fur seal was 9.8 percent (Table 4). Each of the three samples was taken at random and consisted of about 12 aliquots totaling 5 pounds. The aliquots were taken from the ground material as it left the grinder. Even with this attempt at obtaining representative material, the concentrations of oil in the three lots ranged from 8.7 percent to 11.2 percent.

It should be noted, however, that the carcasses were shipped from St. Paul Island to Vancouver, British Columbia, packed in crushed ice. Contact with melting ice during the voyage may have affected the content of moisture in the carcasses and hence may have affected the relative content of oil.

Table 4.—Proximate composition of fur seal commercially ground

Sample	Proximate composition			
	Moisture	Oil	Protein	Ash
	Percent	*Percent*	*Percent*	*Percent*
A	67.3	8.7	21.3	3.4
B	66.6	9.6	21.6	3.1
C	64.8	11.2	21.3	3.3
Average	66.3	9.8	21.4	3.3

Note: Commercially ground samples included bones, flippers, and some blubber but did not include heads, viscera, or hides.

SUMMARY AND CONCLUSIONS

In a preliminary study, analyses of samples of fur-seal carcass indicate that the fur seal contains a high amount of protein, a moderately high amount of oil--due primarily to the presence of blubber, and a high amount of ash--due primarily to the presence of bone.

Analyses of samples of fur-seal meat only show that the meat is very high in protein and low in oil.

Although the data indicate that fur seal varies considerably in composition, the variability did not correlate with sex or time of sampling within the killing season between mid July and late August--at least in the small size of samples tested.

LITERATURE CITED

Horwitz, William (editor).
1955. Official methods of analysis, Association of Official Agricultural Chemists. Association of Official Agricultural Chemists, Washington, D.C., 8th ed., 1008 pp.

MS. #2026

Byproducts plant on St. Paul Island.

Loading ground, packaged seal meat onto a pallet for transportation into the freezer.

The Pribilof Islands in Bering Sea are the homeland of the largest fur seal herd in the world. Here the fur seals come ashore to bear their young on the rocks and sands above tidewater.

CONTENTS

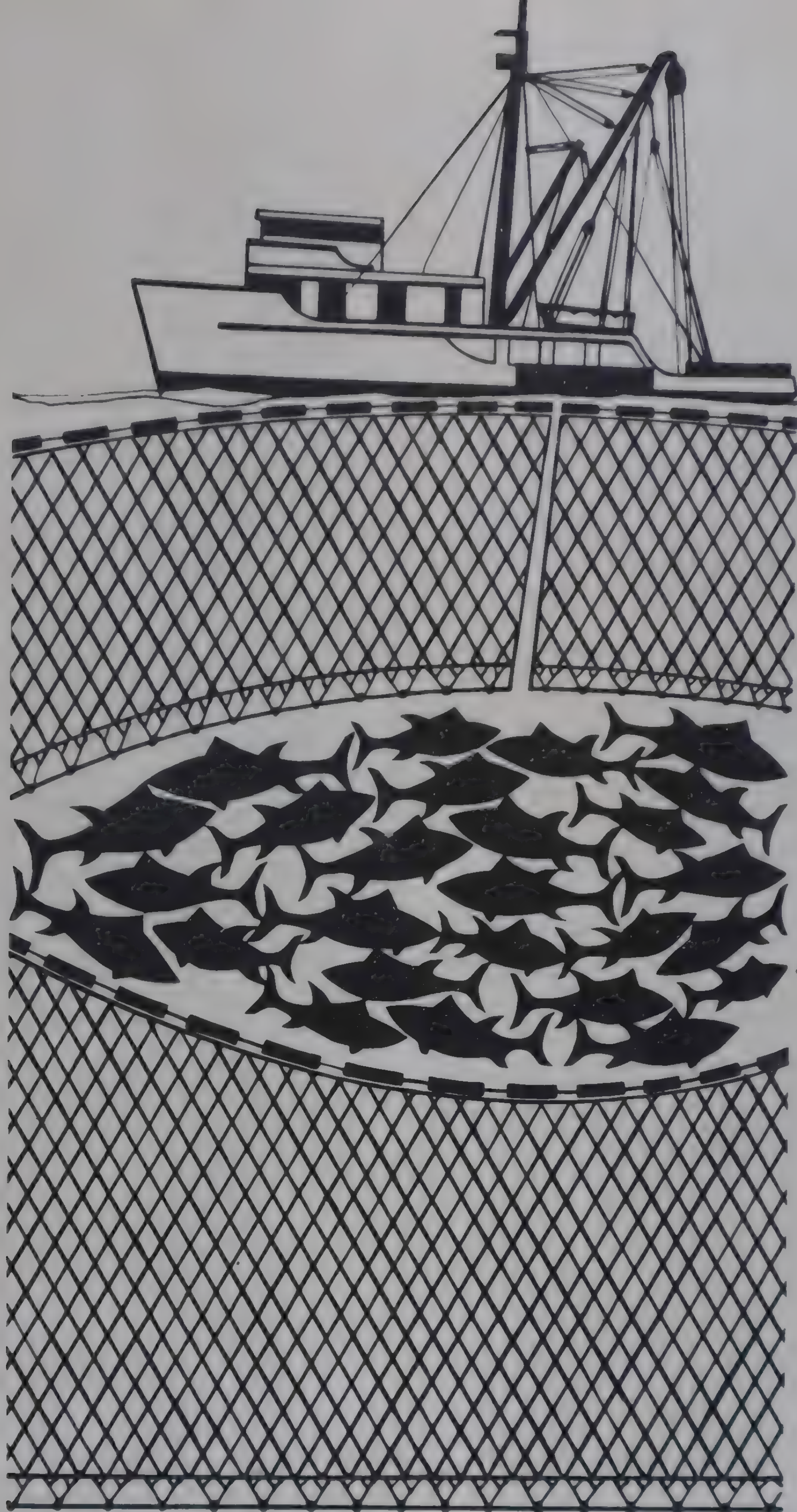
GPO 997-119

UNITED STATES
DEPARTMENT OF THE INTERIOR
U.S. FISH AND WILDLIFE SERVICE
BUREAU OF COMMERCIAL FISHERIES
DIVISION OF PUBLICATIONS
BLDG. 67, U.S. NAVAL AIR STATION
SEATTLE, WASHINGTON 98115

OFFICIAL BUSINESS

Return this sheet to above address, if you do NOT wish to receive this material ☐, or if change of address is needed ☐ (indicate change and give ZIP Code).

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF THE INTE



FISHERY INDUSTRIAL RESEARCH

VOLUME 6 NO. 3

2-10-1970.

United States
Department of the Interior
U.S. Fish and Wildlife Service
Bureau of Commercial Fisheries

Members of the fishing industry and allied interests who wish to receive FISHERY INDUSTRIAL RESEARCH should write to:

Bureau of Commercial Fisheries
Office of Scientific Publications
Bldg. 67, Naval Support Activity
Seattle, Washington 98115

UNITED STATES DEPARTMENT OF THE INTERIOR

Walter J. Hickel, *Secretary*

Fred J. Russell, *Under Secretary*

Leslie L. Glasgow, *Assistant Secretary*
for Fish and Wildlife and Parks

U.S. FISH AND WILDLIFE SERVICE

Charles H. Meacham, *Commissioner*

BUREAU OF COMMERCIAL FISHERIES

Philip M. Roedel, *Director*

FISHERY INDUSTRIAL RESEARCH

Volume 6 -- Number 3

Washington, D. C.
AUGUST 1970

As the Nation's principal conservation agency, the Department of the Interior has basic responsibilities for water, fish, wildlife, mineral, land, park, and recreational resources. Indian and Territorial affairs are other major concerns of America's "Department of Natural Resources."

The Department works to assure the wisest choice in managing all our resources so each will make its full contribution to a better United States — now and in the future.

FEASIBILITY OF USING TENNESSEE RIVER FISH FOR FISHERY PRODUCTS

by

Richard A. Krzeczkowski

ABSTRACT

Populations of reservoir fishes are dominated by species that are of no interest to sport fisherman and that are of low market value. Yet a useful outlet is needed for them. Would they perhaps be suitable for the production of fish meal?

In partial answer to this complex question, the present study investigated the nutritional aspects of some of the principal species of fishes growing abundantly in reservoirs. In this connection, carp, freshwater drum, gizzard shad, and threadfin shad from the Tennessee River (specifically, Kentucky Lake) were harvested commercially and were rendered into press cake and fish meal. The seasonal variations in proximate analyses, the composition of extracted fish oil, the presence or absence of thiaminase in the materials, the concentration of DDT and DDE, and the comparative value of the fish meal in broiler rations were determined.

The study indicated that these species of fishes are nutritionally and physically suitable for the production of fish press cake, meal, and oil.

CONTENTS

Author: Richard A. Krzeczkowski, *Chemist*, Bureau of Commercial Fisheries Technological Laboratory, Ann Arbor, Michigan. Present address: Bureau of Commercial Fisheries Technological Laboratory, 622 Mission Street, Ketchikan, Alaska 99901.
Published May 1970.

CONTENTS—Con.

INTRODUCTION

During the past 30 years, many large reservoirs have been built within the United States, primarily for flood control, irrigation, navigation, and the production of electric power. A byproduct of these reservoirs has been the creation of fisheries and recreational resources that, in some areas, have gained an importance equal to that of the original purpose. In these areas, game fishes have been utilized to a great extent by sport fishermen. Those species, however, that are of no interest to sport fishermen and particularly those species that have a relatively low market value as commercial fish are not being utilized. Yet, these fishes of low value commonly dominate the populations of reservoir fishes. The Bureau of Commercial Fisheries Exploratory Fishing and Gear Research staff at Ann Arbor, Michigan, (1969) has estimated that the potential harvest for nongame fish in the Mississippi River drainage system is 450 million pounds annually. Less than 20 percent (70 to 90 million pounds) of these fish are harvested each year.

Where commercial fisheries have been established, the production is usually limited to species with a good market value--the production of catfish and buffalo fish is a good example. Rarely are fishes of low value--such as carp (*Cyprinus carpio*), freshwater drum (*Aplodinotus grunniens*), gizzard shad (*Dorosoma cepedianum*), and threadfin shad (*D. pentenense*)--taken in the quantities that are commensurate with their abundance. If the use of reservoir aquatic resources is to be maximized and if regulatory agencies are to use commercial fisheries as a tool to effect the management of fishes in reservoirs, practical means of utilizing the abundant but low-value fishes is highly desirable.

The only commercial potential now appears to be in the industrial processing of the low-value fishes for pet food, fur-animal food, fish meal, or related nutritional uses. The criteria of economics that are imposed on an industrial fishery are stringent and have prevented the establishment of significant reservoir fisheries of this kind. The species of fishes that are used most commonly for the production of meal are marine members of the herring family, which are harvested cheaply in vast quantities and which have proved to be nutritionally valuable for poultry.

If we bypass the economics of fish processing and the problems attending the sale of the product at a competitive price, we are still faced with the fundamental problem of the nutritional value of the products. Therefore, the possibility of using fresh-water species for the production of fish meal requires that the suitability of these species as the ingredients of a meal used in animal rations be established. The overall purpose of this study accordingly was to explore the nutritional feasibility of utilizing low-value species from a typical reservoir, such as Kentucky Lake in the Tennessee River, for processing into fish press cake, meal, and oil.

The species chosen for study were carp, freshwater drum, gizzard shad, and threadfin shad, all of which are abundant. Fishery biologists from Tennessee Game and Fish Commission and Tennessee Valley Authority estimate that a reservoir such as Kentucky Lake could yield from 15 to 30 million pounds of carp, freshwater drum, and shads annually.

The specific purposes of the study were to determine (1) the seasonal variation in the concentration of protein, oil, ash, and moisture

in the raw fish, press cake, and fish meal; (2) the composition of the extracted fish oil; (3) the presence or absence of thiaminase (a vitamin B_1 antimetabolite) in the products; (4) the seasonal variation in the concentration of certain pesticides in the raw fish and in the products; and (5) the nutritional value of the fresh-water fish meal as compared with that of menhaden (*Brevoortia tyrannus*) meal when included in broiler rations.

I. SEASONAL VARIATION IN THE PROXIMATE COMPOSITION OF THE RAW FISH, THE PRESS CAKE, AND THE FISH MEAL

A. MATERIALS AND METHODS

The following sections describe (1) the raw materials used and preparation of the products from them and (2) the analytical procedures used.

1. Raw Materials and Preparation of Products

a. Raw materials.—The samples of fish were collected by the use of commercial trawl and gill nets. All the samples were collected in Kentucky Lake, Tennessee, in the area of Johnsonville, Tennessee. The fish were harvested during August and November 1966, and January, February, March, April, and June 1967 for seasonal variation. They were segregated by species, packed in ice as soon as they were caught, and frozen within 24 hours. The frozen fish were stored at about 0° F. until they were transported frozen to the laboratory at Ann Arbor. Upon arrival at the laboratory, they were stored at −30° F. until they were processed.

The carp were 16.4 to 22 inches long and weighed 0.5 pounds to 5 pounds.

The freshwater drum were 8 to 19 inches long and weighed 0.33 pounds to 1.5 pounds.

The catch of shad was composed of 80 percent threadfin and 20 percent gizzard shad by number. This ratio represented the commercial catch (net-run) of shad, so no attempt was made to separate the two species because commercially such a separation would not be practical. The average length of these fish varied from 2.7 to 8.3 inches; the weight varied from 100 fish per pound to 11 fish per pound. In all samplings and measurements, the ratio of 80 percent threadfin shad to 20 percent gizzard shad by number was maintained.

The condition and quality of all fishes were excellent.

b. Preparation of products.—The fishes were conventionally wet rendered to produce press cake and oil; and fish meal was made from the press cake.

(1) Press cake and oil.—The temperature of 100 pounds of whole fish of each species was allowed to rise to about 0° F., and the frozen fish were then ground once through a meat chopper having a plate with holes ¼-inch in diameter.

The ground fish was cooked to 203° F. in 100-pound batches by use of a steam-jacketed kettle and the direct injection of steam.

While the resulting cooked material was still hot, it was pressed in a 4-foot, 3-stage screw press. The yield of press cake was 50 to 65 percent.

Portions of the raw, ground fish and press cake were sampled, and the samples were stored at −30° F. for chemical analysis.

Oil was decanted from the press water, and a sample of it was also taken for analysis.

(2) Fish meal.—The press cake to be processed into fish meal was dried in a vacuum, steam-jacketed dryer at 15 inches of mercury vacuum and 5 pounds per square inch steam. The material was dried until the percentage of water was less than 10. The dried material was then pulverized in a hammer mill, which

had a screen with 0.05-inch openings. The resulting fish meal was sampled for analysis, and the sample was stored at −30° F. The yield of fish meal was 17 to 23 percent of the amount of raw fish used.

2. Analytical Procedures

The following sections describe (a) the methods used in the preparation of the samples for proximate analysis and (b) the methods of proximate analysis used.

a. Sample preparation.—Frozen samples of raw fish and of press cake were ground twice through a meat chopper having a plate with holes ⅛-inch in diameter and were blended by stirring before being sampled. The samples of fish meal were weighed directly from the milled, frozen stock.

b. Proximate analysis.— All samples were analyzed in duplicate for the percentages of protein, oil, ash, and water by the procedures of the Association of Official Agricultural Chemists (Horwitz, 1960).

B. RESULTS

Differences in proximate composition as influenced by species and season were investigated for (1) the raw fish, (2) the press cake, and (3) the fish meal.

1. Raw Fish

Table 1 indicates a wide variation in the concentrations of protein, oil, ash, and water among the three species as well as among the individual specimens within a given species.

The percentage of protein ranged from 14.17 to 18.46, except for two samplings. The shad harvested on August 27, 1966, had 13.19 percent protein, and the carp harvested on December 9, 1966, had 20.50 percent protein. The average percentages of protein in each species was as follows: carp, 17.18; freshwater drum, 15.28; and shad, 14.38. The data do not reveal any significant seasonal variation in the percentage of protein.

The range in the percentage of oil was large in the shad and freshwater drum and appeared to be seasonally dependent. The percentage of oil for carp was lowest in the spring (4.0 percent) and ranged higher during the rest of the year (6.8 to 9.6 percent). The percentage of oil for freshwater drum was, likewise, low during the spring--2 percent--and was higher during the rest of the year--7.3 percent to 10.7 percent. The percentage of oil for shad ranged from a low of 2.9 during the spring and summer to a high of 8.8 in the winter.

The average percentage of ash in the fishes ranged from 3.29 to 5.78. The percentage of ash was lowest in shad and highest in freshwater drum. The percentage of ash in shad and freshwater drum was lowest during the winter, and this low percentage for ash corresponded to a high percentage for oil.

The percentage of water ranged from a low of 65.91 to a high of 79.26, with an average of 72.97 for all the fishes. Shad had a high percentage of water; whereas, carp and freshwater drum had lower values.

As would be expected, the percentage of oil and of water varied inversely with one another. The percentage of oil plus water in all the fishes ranged between 77 and 83.

2. Press Cake

The percentage of protein showed no seasonal dependency and ranged between 20.20 and 26.30 except for carp press cake (dated February 2, 1967), which had a percentage of 28.28.

The percentage of ash ranged between 6.11 and 15.89. The percentage of ash in freshwater drum and shad press cake appears to be dependent on the percentage of oil in the raw sample. A lower percentage of oil in the raw fish corresponds to a higher percentage of ash in the press cake. The percentage of ash in carp press cake varied directly with the percentage of oil in the raw carp.

The percentage of water ranged from 55.54 to 65.92 for all press cakes. The percentage of oil ranged from 2.90 to 8.74. In all samples, the percentage of oil plus water ranged between 61.3 to 71.2. All but freshwater drum press cake (dated April 1967) with a value of 58.4 percent was within this range.

Table 1.–Seasonal variation in length, weight, and composition of Tennessee River fish

Species and state	Average length[1]	Average weight[1]	Time of year	Protein	Oil	Ash	Water	Concentration of pesticides p,p'-DDE & p,p'-DDT		Thiaminase activity
	Inches	*Pounds*	*Month*	*Percent*	*Percent*	*Percent*	*Percent*	*P.p.m.*	*Percent of original*[2]	*Present or absent*
Shad:										
Raw fish ...	2.7	.01	Aug.	13.19	3.39	4.62	79.26	0.35	100	+
Press cake ..			1966	24.33	4.52	12.43	57.84	0.72	100	–
Fish meal ..				53.98	9.32	26.95	10.00	1.50	85	–
Raw fish ...	4.1	.2	Nov.	14.70	8.8	3.29	73.20	0.90	100	+
Press cake ..			1966	21.58	5.18	7.64	65.90	0.45	40	–
Fish meal ..				57.39	14.11	18.67	10.00	2.10	36	–
Raw fish ...	4	.2	Jan.	14.17	8.18	3.38	73.75	1.04	100	+
Press cake ..			1967	21.62	5.09	6.11	65.72	0.63	41	–
Fish meal ..				61.85	11.49	16.90	10.00	1.85	36	–
Raw fish ...	6.1	.1	Mar.	14.28	3.17	4.37	78.18	0.93	100	+
Press cake ..			1967	25.23	4.98	8.02	61.77	1.32	70	–
Fish meal ..				59.43	10.97	19.76	10.00	3.05	66	–
Raw fish ...	8.3	.8	June	15.55	2.86	5.28	76.31	0.80	100	+
Press cake ..			1967	26.30	3.36	10.76	59.58	0.61	40	–
Fish meal ..				61.29	5.58	23.39	10.00	1.53	37	–
Carp:										
Raw fish ...	18.3	4.9	Aug.	17.50	9.64	4.76	68.81	1.50	100	+
Press cake ..			1966	21.32	4.70	8.64	65.54	0.96	32	–
Fish meal ..				59.32	10.62	19.42	10.00	1.65	22	–
Raw fish ...	16.4	3.5	Nov.	20.50	8.95	4.55	65.91	2.48	100	+
Press cake ..			1966	24.53	4.27	7.89	62.40	3.60	72	–
Fish meal ..				60.65	10.91	17.52	10.00	5.46	44	–
Raw fish ...	17	5	Jan.	16.46	6.81	3.64	72.05	3.06	100	+
Press cake ..			1967	23.66	6.35	6.54	60.62	3.00	48	–
Fish meal ..				57.89	15.99	15.79	10.00	7.38	48	–
Raw fish ...	20.25	5.5	Feb.	18.46	7.89	4.72	68.93	2.52	100	+
Press cake ..			1967	28.20	7.69	7.99	56.12	2.25	45	–
Fish meal ..				58.22	15.02	16.86	10.00	7.37	43	–
Raw fish ...	22	5	Apr. 1967	18.47	4.13	5.55	71.85	--	–	+
Raw fish ...	18	8	June	15.40	7.91	4.09	72.60	1.10	100	+
Press cake ..			1967	20.20	6.94	10.78	62.08	.90	41	–
Fish meal ..				55.97	9.29	24.95	10.00	2.02	37	–
Freshwater drum:										
Raw fish ...	13	1.4	Aug.	15.57	7.29	5.57	71.51	2.11	100	–
Press cake ..			1966	25.76	4.22	10.64	58.69	0.97	28	–
Fish meal ..				56.78	6.45	25.68	10.00	1.50	15	–
Raw fish ...	19	1.9	Nov.	16.74	10.72	4.18	69.10	3.60	100	–
Press cake ..			1966	24.22	5.59	8.58	61.62	0.90	15	–
Fish meal ..				57.68	13.12	18.64	10.00	2.05	11	–
Raw fish ...	9	12	Mar.	15.24	1.95	5.36	77.45	1.26	100	–
Press cake ..			1967	23.83	3.26	14.54	58.37	1.29	60	–
Fish meal ..				54.23	5.70	30.29	10.00	1.89	30	–
Raw fish ...	8	1.75	Apr.	14.63	2.14	5.78	77.45	1.22	100	–
Press cake ..			1967	25.67	2.90	15.89	55.54	1.70	84	–
Fish meal ..				52.28	5.65	32.29	10.00	3.50	57	–
Raw fish ...	9.5	3.25	June	14.21	9.11	5.41	71.27	1.74	100	–
Press cake ..			1967	20.60	8.74	8.20	62.46	1.30	45	–
Fish meal ..				52.98	15.91	21.35	10.00	3.54	41	–

[1] The average length and weight were calculated for whole fish from 100-pound batches.
[2] The percent of the original concentration of pesticide is accurate to ±5 percent.

Most of the values shown were directly dependent on pressing efficiency and on the physical consistency of the cooked material. Cooked carp was difficult to press, inasmuch as this material slipped in the screw press. This unfavorable pressing characteristic was probably due to a high content of eggs in most of the carp used. The percentage of water

plus oil for all samples of press cake appears to be directly influenced by the percentage of oil in the raw fishes.

3. Fish Meal

The proximate composition of all the meals is reported on the basis of 10 percent of water. Where the actual concentration of water in a meal was less than 10 percent, the data were adjusted to the 10-percent basis to facilitate the comparison of data.

The percentage of oil in freshwater drum and shad meal varied directly with the percentage oil in the raw fish and ranged from 5.58 to 15.91. Oddly, most of the oil values for carp meal varied inversely with the oil values for the raw fish. This inverse relation is believed to be due to pressing difficulties caused by a high content of eggs when the percentage of oil was low. One lot of carp (dated April 6, 1967), which was lowest in oil content but highest in egg content, would not compress; hence, no data are given for its corresponding press cake and meal.

The percentage of ash in all the meals varied from 16.8 to 32.29 and appears to be inversely related to the percentage of oil in the meal. In the carp and shad meals, the ash varied from 16.80 to 26.95. The percentage of ash was highest in the freshwater drum meal (18.64 to 32.29) probably because of the characteristic large bony structure in these fish.

II. ANALYSES OF THE EXTRACTED FISH OIL

Reported here are the analyses of (A) the gross properties of the oil as revealed by the iodine value, saponification value, and color of the oil, and (B) the fatty acid composition of the oil.

A. GROSS PROPERTIES

1. Materials and Methods

The oil samples, which were decanted from the press water (fish caught in November 1966) as was described in Section I, were analyzed for iodine value (Wijs) and saponification value by the official methods of the American Oil Chemists Society (Mehlenbacher, Hopper, and Sallee, 1955). Color values were obtained by means of a Gardner color comparator.

2. Results

The gross properties of the oil were closely similar for the three species. The iodine values found for the rendered carp, freshwater drum, and shad oil ranged from 121 to 123, and the saponification values ranged from 189 to 192 (Table 2). All the oils were light in color and ranged from 6 to 13 Gardner.

Table 2.—Gross properties of oils from the press liquor of carp, freshwater drum, and shad

Species	Wijs iodine value	Saponification value	Gardner color value
Carp	121	189	11 to 13
Freshwater drum .	123	190	6 to 10
Shad	125	192	10 to 12

B. FATTY ACID COMPOSITION

1. Materials and Methods

Oils obtained from the various fishes as was described in the preceding section were saponified and converted to the methyl esters of the constituent fatty acids for subsequent gas-liquid chromatography.

The methyl esters were prepared by a semimicro methanolysis adapted to the method of Metcalfe, Schmitz, and Perla (1966). The methyl esters were analyzed with a Perkin-Elmer 810 gas chromatograph[1] equipped with a dual flame ionization detector. The columns used were each composed of stainless-steel tubing 0.210 inch in inside diameter and 8 feet in length. The column contained 4.0 percent (by weight) of diethylene glycol succinate polyester supported on 80-mesh to 100-mesh

[1] The use of trade names is merely to simplify descriptions; no endorsement is implied.

chromosorb G. The following operating conditions were used: flesh heat temperature 280° C., column temperature 170° C., detector temperature 200° C., and 50 milliliters per minute nitrogen carrier gas flow.

The gas-liquid chromatographic peaks of the samples were identified by comparison with standard peaks obtained from pure methyl esters. Equivalent chain-length values were determined according to the method of Miwa (1963) and were compared with values reported by Hofstetter, Sen, and Holman (1965) for identifying peaks for which no pure methyl ester was available. The area of each chromatographic peak representing a fatty acid present was obtained by multiplying the height of each peak by the width at half-weight. The area of each peak was then related to the total peak area to obtain the percentage of each specific fatty acid.

The analyses were performed in duplicate from fish caught in November 1967. The large components (Table 3) are estimated to be accurate to about ±6 percent; the medium-size components, to ±10 percent; and the small components, to ±60 percent. The data are reported to two places simply to reveal the relative amounts of the small components.

Table 3.—Comparison of the total fatty acid distribution in oils from press liquor of carp, freshwater drum, and shad

Fatty acids	Fatty acid distribution in oil from:		
	Carp	Freshwater drum	Shad
Ratio C atoms to double bonds	*Weight percent*	*Weight percent*	*Weight percent*
Saturated acids			
12:0	0.11	0.13	0.20
14:0	2.84	2.70	3.93
15:0[1]	0.78	1.96	2.66
16:0	18.08	19.53	22.10
17:0	0.79	1.15	1.74
18:0	2.06	2.32	3.41
19:0[2]	0.42	Trace	0.50
20:0	0.26	Trace	Trace
Monoenoic acids			
15:1	0.30	0.46	--
16:1	25.54	26.42	10.32
17:1[3]	1.26	2.95	1.81
18:1	34.31	27.97	32.32
19:1 ?	0.42	0.51	--
20:1	1.45	1.65	1.31
22:1	0.21	Trace	Trace
Dienoic acids			
18:2	1.62	3.32	4.12
20:2 ?	0.29	0.32	1.01
Trienoic acids			
16:3ω4 ?	0.27	0.41	0.53
18:3	1.04	0.90	5.41
20:3	0.22	0.16	0.37
22:3	0.28	0.37	0.58
Tetraenoic acids			
18:4	0.56	0.56	0.83
20:4ω3	1.14	1.45	1.75
20:4ω6	0.32	0.32	0.62
22:4	0.20	0.23	0.72
Pentaenoic acid			
21:5ω2 ?	0.21	0.13	--
20:5	3.38	2.08	1.98
22:5	0.59	0.93	0.84
Hexaenoic acid			
22:6	1.04	0.99	1.65

[1] Includes iso 15:0.
[2] Combined pair of 19:0 and 16:4ω1.
[3] Combined pair of 17:1 and 16:2.

2. Results

The percentage of total saturated fatty acids ranged between 25 and 35 for all the oils (Table 3). Fatty acid 16:0 was the dominating saturated fatty acid accounting for 18 to 22 percent of the total fatty acid distribution. The distribution of saturated fatty acids is similar in carp and freshwater drum; shad oil, however, contained about 3 percent more fatty acid 16:0 and 2 percent more fatty acid 14:0.

Fatty acids 16:1 and 18:1 dominate the monoenoic distribution, which accounts for 46 to 64 percent of the total fatty acid distribution. Fatty acid 18:1 was found to be the major acid in carp with 34 percent, freshwater drum with 28 percent, and shad with 32 percent. Shad contained only 10 percent of fatty acid 16:1 as compared with 26 percent in carp and freshwater drum.

The polyunsaturated fatty acid distribution for oil of carp and freshwater drum is similar and accounts for about 12 percent of the total fatty acid distribution. Shad oil, however, contained about 20 percent polyunsaturates. This difference was mainly due to more dienoic acids 18:2 and 20:2 and trienoic acid 18:3.

Values shown in Table 3 are similar to values found by Ackman (1967) in four North American fresh-water fishes, except that Ackman found slightly higher values for pentaenoic acid 20:5 and hexaenoic acid 22:6.

III. THIAMINASE ACTIVITY IN THE PRODUCTS

The enzymatic activity of thiaminase was determined chemically by use of the method described by Gnaedinger (1965) in which thiamine is oxidized to thiochrome, a fluorescent compound.

All raw samples except those of freshwater drum showed thiaminase activity; however, all resulting rendered products were determined to be thiaminase inactive. [Fortunately, thiaminase is readily inactivated by heat (Gnaedinger and Krzeczkowski, 1966)].

IV. SEASONAL VARIATION IN THE CONCENTRATION OF PESTICIDES

A. METHODS AND MATERIALS

D D T (Dichlorodiphenyltrichloroethane) and DDE (the minus-HCL derivative of DDT) were determined by a rapid procedure developed at the Bureau of Commercial Fisheries Technological Laboratory, Ann Arbor, Michigan, which has proved convenient where a large number of samples are analyzed. Briefly, the procedure consists of:

a. Saponifying the sample with KOH.

b. Extracting the saponified material with hexane.

c. Analyzing the hexane extract by gas-liquid chromatography.

An Aerograph gas chromatograph equipped with a 9-foot glass column having an inside diameter of 3.5 millimeters was used. The front 60 percent of the column was packed with 5 percent QF-1 on Gas-chrom Q 100 to 120 mesh; the rear 40 percent was packed with 5 percent DC-11 on Gas-chrom Q 100 to 120 mesh. With this instrumental setup and procedure, p,p'-DDE and p,p'-DDT came off as one peak.

B. RESULTS

The analysis of DDT and DDE indicates a possible seasonal variation in whole raw carp and freshwater drum (Table 1). The concentration of the pesticides in carp ranged from 1.10 to 1.50 parts per million in the summer and from 2.48 to 3.06 parts per million during the rest of the year. The June and August samples shown are 1 year apart, indicating that the pesticide concentration gained in the fall and winter, but decreased in the summer.

The concentration of pesticides in freshwater drum appears lowest in the spring with 1.2 to 1.26 parts per million. August and June samples, which are 1 year apart, show higher values of 1.74 to 2.11 parts per million. The November sample has a high reading of 3.6 parts per million indicating that pesticide values in freshwater drum were highest in the fall and lowest in the spring.

Shad samples do not show a strong seasonal association. All values were between 0.80 and 1.04 parts per million except the August sample, which had a low of 0.35 parts per million.

Although the concentration of pesticide increased in the press cake and the fish meal, the amount of pesticide decreased greatly. Table 1 shows that 15 to 84 percent of the original amount of pesticide remained in the press cake and that 11 to 66 percent remained in the fish meal. Only the percentages for the shad collected in August rose above this range.

The pesticide appears to be associated with fish oil; thus, the reduction in the amount of pesticide in the press cake and the fish meal was directly related to the amount of oil rendered out of the raw fish.

V. RELATIVE NUTRITIONAL QUALITY FOR BROILERS

The fifth specific purpose of the work reported here was to provide a quantity of carp and shad fish meal to the University of Tennessee for broiler-feeding trials. Freshwater drum was not included because of limited facilities. The purpose of these feeding trials was to determine whether the fresh-water fish meals differ significantly in nutritional value from that of menhaden meal when included in broiler rations. Menhaden meal, which is of marine origin, is the fish meal produced in largest quantity in the United States and is used extensively in rations for broilers.

For the broiler-feeding study by the University of Tennessee, 945 pounds of carp and 921 pounds of shad were taken from the Tennessee River in January 1967 and were rendered in the Bureau of Commercial Fisheries pilot plant at Ann Arbor into 156 pounds of shad fish meal and 213 pounds of carp fish meal. The Bureau of Commercial Fisheries Technological Laboratory at College Park, Maryland, provided the University of Tennessee with 400 pounds of menhaden fish meal, which was used as the control meal.

Table 4 shows the proximate analyses of the meals prepared experimentally at Ann Arbor and the menhaden meal.

Table 4.–Proximate analyses of carp and shad prepared experimentally and menhaden meal prepared commercially

Fish meal	Protein	Oil	Ash	Water
	Percent	*Percent*	*Percent*	*Percent*
Carp	59.96	16.64	16.43	6.03
Shad	62.79	11.67	17.16	8.50
Menhaden	61.52	12.08	18.20	8.20

Bletner and Goan (1968) have reported on the results of the feeding trials. They concluded that the fish meals prepared from carp and shad were equal to menhaden fish meal for growth and feed efficiency.

SUMMARY AND CONCLUSIONS

As part of an effort to find a use for reservoir fish of little interest to sport fishermen and of low commercial value, the composition of carp, freshwater drum, and shad from Kentucky Lake on the Tennessee River was investigated.

In the raw fish, the percentage of protein ranged mostly from about 14 to 18. The data revealed no significant seasonal variation in the percentage of protein. The percentage of oil ranged from about 3 to 10. The percentage appeared to be seasonally dependent and tended to be lowest during the spring. The percentage of ash ranged from about 3 to 6. It tended to be low when the percentage of oil was high.

In the fish cake, the percentage of protein ranged mostly from about 20 to 26, the percentage of oil ranged from about 3 to 9, and the percentage of ash ranged from about 6 to 16. A high percentage either of oil or of eggs in the raw material reduced pressing efficiency.

The gross properties of the oil were closely similar for all three species. The iodine value ranged from 121 to 123, the saponificat value ranged from 189 to 192, and the were all light in color.

The percentage of saturated fatty acid the rendered oils ranged between 25 and 35, the percentage of the monoenoic acids 16:1 and 18:1 ranged between 42 and 59, and the percentage of the polyunsaturated acids was 11 to 20, with fatty acids 20:5 and 22:6 being lower than that usually found in fresh-water fishes and varying from about 3 to 4 percent. These oils are high in fatty acids 16:1 and 18:1 and should be of industrial value.

All samples of raw fish except those of freshwater drum showed thiaminase activity; however, all the rendered products were thiaminase inactive.

In the raw fish, the concentration of DDE and DDT ranged from about 1.1 to 3.1 parts per million for carp, from about 1.2 to 3.6 parts per million for freshwater drum, and from about 0.35 to 1.0 parts per million for shad.

The concentration of pesticides showed a seasonal change that varied somewhat from one species to another. Owing to the association of the pesticide with fish oil and to the greater relative removal of water than of oil from the press cake and fish meal, the concentration of pesticide increased in the press cake and fish meal, although the total amount of pesticide present was greatly reduced. The decrease in the total amount of pesticide in the press cake and fish meal was accounted for by the amount partitioned into the rendered oil.

The composition of commercially made fish meals vary considerably because of the variety of raw material used and the use of several different processing techniques. The composition of menhaden meals produced by Atlantic processors in 1960 is as follows: protein 53.6 to 66.5 percent, oil 3.7 to 13.7 percent, ash 14.7 to 27.0 percent, and moisture 5.2 to 15.4 percent. The composition of menhaden meals from Gulf of Mexico processors in 1960 shows yet a different range in analysis as follows: protein, 56.5 to 66.7 percent; oil, 9.0 to 15.2 percent; ash, 17.8 to 21.9 percent; and moisture, 6.1 to 8.7 percent.[2]

Five fish meals each of carp, freshwater drum, and shad were prepared in this study from samples harvested in the winter, spring, summer, and fall seasons. In these fish meals, the protein ranged from about 52 to 62 percent; oil, 6 to 16 percent; ash, 7 to 32 percent; and moisture, 5 to 10 percent. All these values are reasonably close to those of commercially produced menhaden meals. But the quality of protein, oil, and ash rather than the content determines the nutritive value. This quality is best determined in actual feeding studies.

Work at the University of Tennessee showed that, with broilers, carp meal and shad meal were each equal to menhaden meal for growth and feed efficiency.

The overall conclusions from the work is that the products from carp, freshwater drum, and shad are closely similar and that these species of fishes are nutritionally and physically suitable for the production of fish press cake, fish meal, and fish oil.

ACKNOWLEDGMENT

John Conder of the Tennessee Game and Fish Commission collected the samples, and Robert Reinert of the Bureau of Commercial Fisheries analyzed the samples for pesticides.

This work was sponsored by the U.S. Department of Commerce, Economic Development Administration, under Technical Assistance Project No. 958.

LITERATURE CITED

Ackman, R. G.
1967. Characteristics of the fatty acid composition and biochemistry of some fresh-water fish oils and lipids in comparison with marine oils and lipids. Comp. Biochem. Physiol. 22: 907-922.

Bletner, J. K., and H. C. Goan.
1968. TVA lakes fish meal as a feedstuff for chickens. Tenn. Agr. Exp. Sta., Tenn. Farm Home Sci., Progr. Rep. 65, pp. 15-18.

Bureau of Commercial Fisheries, Exploratory Fishing and Gear Research Base, Ann Arbor, Michigan, Staff.
1969. A study to determine the feasibility of establishing a fish meal industry in Tennessee. U.S. Dep. Commer., Econ. Develop. Admin. Tech. Assistance Proj. No. 958,

[2] Data provided by the Bureau of Commercial Fisheries Technological Laboratory, College Park, Maryland, November 14, 1960.

Gnaedinger, R. H.
1965. Thiaminase activity on fish: An improved assay method. U.S. Fish. Wildl. Serv., Fish. Ind. Res. 2(4): 55-59.

Gnaedinger, R. H., and R. A. Krzeczkowski.
1966. Heat inactivation of thiaminase in whole fish. Commer. Fish. Rev. 28 (8): 11-14.

Hofstetter, H. H., N. Sen., and R. T. Holman.
1965. Characterization of unsaturated fatty acids by gas-liquid chromatography. J. Amer. Oil Chem. Soc. 42: 537-540.

Horwitz, William (chairman and editor).
1960. Official methods of analysis of the Association of Official Agricultural Chemists. Association of Official Agricultural Chemists, Washington, D.C., 9th ed., 832 pp.

Mehlenbacher, V. C., T. H. Hopper, and E. M. Sallee (editors).
1955. Official and tentative methods of the American Oil Chemists Society. American Oil Chemists Society, Chicago, Illinois, 3d ed.

Metcalfe, L. D., A. A. Schmitz, and J. R. Pelka.
1966. Rapid preparation of fatty acid esters from lipids for gas chromatographic analysis. Anal. Chem. 38: 514.

Miwa, T. K.
1963. Identification of peaks in gas-liquid chromatography. J. Amer. Oil Chem. Soc. 40: 309-313.

MS. #2024

ECONOMIC STUDY OF THE SAN PEDRO WETFISH BOATS

by

William F. Perrin and Bruno G. Noetzel

ABSTRACT

The San Pedro wetfish fleet is shrinking in size and is not yielding good wages for fishermen or good returns to investors. A study was made to determine if improvement of the economic state of the antiquated fleet might be accomplished by the construction of new, efficient vessels, both for replacements and for expansion of the fleet to harvest underused stocks of jack mackerel and anchovies in the region of the California Current. The investigation yielded two conclusions: (1) the construction of new vessels--even if subsidized--is not economically feasible at present rates of catch and prices of fish and (2) the expansion of the fleet through acquisition of surplus vessels from other fisheries at relatively favorable cost is feasible, given sufficient demand for wetfish at present prices.

CONTENTS

Authors: William F. Perrin, *Fishery Biologist*, Bureau of Commercial Fisheries Fishery-Oceanography Center, P.O. Box 271, La Jolla, California 92037, and Bruno G. Noetzel, *Industry Economist*, Bureau of Commercial Fisheries Division of Economic Research, 7338 Baltimore Avenue, College Park, Maryland 20740.
Published June 1970.

INTRODUCTION

San Pedro is the major seaport for Los Angeles, California. San Pedro wetfish[1] boats (Figure 1) fish currently for mackerel, bonito, anchovies, and tuna in local waters and land them in a fresh unfrozen condition. When Pacific sardines, used for canning and reduction purposes, were available, these boats harvested most of the production of this species. In recent years with changed resource and economic conditions, vessel operators in this fleet have been financially hard-pressed because of rising costs coupled with static fish prices. At the same time, large underused populations of mackerel and anchovies are reported to exist in the California Current region (Ahlstrom, 1968) within the range of the fleet. If these resources are to be harvested by U.S. fishermen, the wetfish fleet would seem to be the most feasible fleet to expand, either through recruitment of available vessels from other fisheries or through the construction of new vessels. Motivated by these considerations, the Bureau of Commercial Fisheries in 1968 began an investigation of the present financial condition of the fleet and the economics of the operations of wetfish boats. This report presents the results of the study. The introduction presents background material on the makeup, history, landings, and operations of the San Pedro fleet, states the precise aims of the study, and describes the data base used.

The San Pedro wetfish-boat fleet is part of the roundhaul fleet, which is made up of

[1] Wetfish are here defined to include jack mackerel *(Trachurus symmetricus)*, Pacific mackerel *(Scomber japonicus)*, Pacific sardine *(Sardinops caerulea)*, and bonito *(Sarda chiliensis)* for canning and also for the fresh-fish market; and northern anchovy *(Engraulis mordax)* for reduction.

Figure 1.–The *North Pacific*, a typical San Pedro wetfish boat.

four types of vessels: (1) tunaboats, (2) combination boats, (3) wetfish boats, and (4) miscellaneous small roundhaul boats.

(1) Tunaboats. Tunaboats are large, long-range purse seiners that vary in fish capacity from 100 to 800 short tons and that fish almost solely for tuna--yellowfin tuna (*Thunnus albacares*) and skipjack tuna (*Katsuwonus pelamis*) off Mexico, Central America, South America, and Africa; and bluefin tuna (*Thunnus thynnus*) and albacore tuna (*T. alalunga*) off California and Mexico. McNeely (1961) has described the purse-seining gear used and the methods of fishing. Green and Broadhead (1965) have described and analyzed the costs and earnings of tropical tunaboats.

(2) Combination boats. Combination boats are purse seiners that vary in fish capacity from 140 to 160 tons and are medium-range vessels that fish primarily for tuna off California and Mexico and for wetfish mostly off California, with tuna making up the major part of the catch. In 1967, eight combination boats were in the San Pedro fleet.

(3) Wetfish boats. Wetfish boats are relatively small purse seiners that vary in fish capacity from 25 to 160 tons and that are 40 to 86 feet long overall. They operate within 100 miles of San Pedro. Individual trips last from 1 to 10 days; the average trip is between 1 and 2 days. Scofield (1951) has described the vessels, gear, and fishing methods. Recent technological developments in the fleet, including the adoption of nylon nets and hydraulic net-hauling blocks, have paralleled those described by McNeely (1961) for the tunaboat fleet. These boats fish primarily for wetfish. A significant proportion of their catch, however, in terms of value is made up of bluefin tuna and albacore tuna (see the wetfish fleet landings below). The number of San Pedro wetfish boats decreased from 47 in 1958 to 25 in 1968 (Figure 2); the greatest reduction was in boats in the size range of 25 to 50 tons.

(4) Miscellaneous small roundhaul boats. Small roundhaul boats include very small purse seiners that vary in fish capacity from 5 to 25 tons and "lampara" boats that vary in fish capacity from 5 to 40 tons and that fish for wetfish, squid (*Loligo opalescens*), anchovies--for use as bait in sport fishing--and a wide variety of other species landed primarily for the fresh-fish markets.

Of these four types of vessels in the San Pedro roundhaul fleet, wetfish boats (Category 3 above) were the subject of this study.

Wetfish boats have had a history of coping with adversity. The decline of the California sardine fishery (Figure 3) left a sizable fleet of small purse seiners on the West Coast in need of profitable employment. Some turned to seining of salmon or tropical tunas, some converted to trawling, and many became the property of foreign fishing companies and left U.S. waters; but some boats, especially those at Monterey and San Pedro, expanded their activities on jack mackerel, Pacific mackerel,

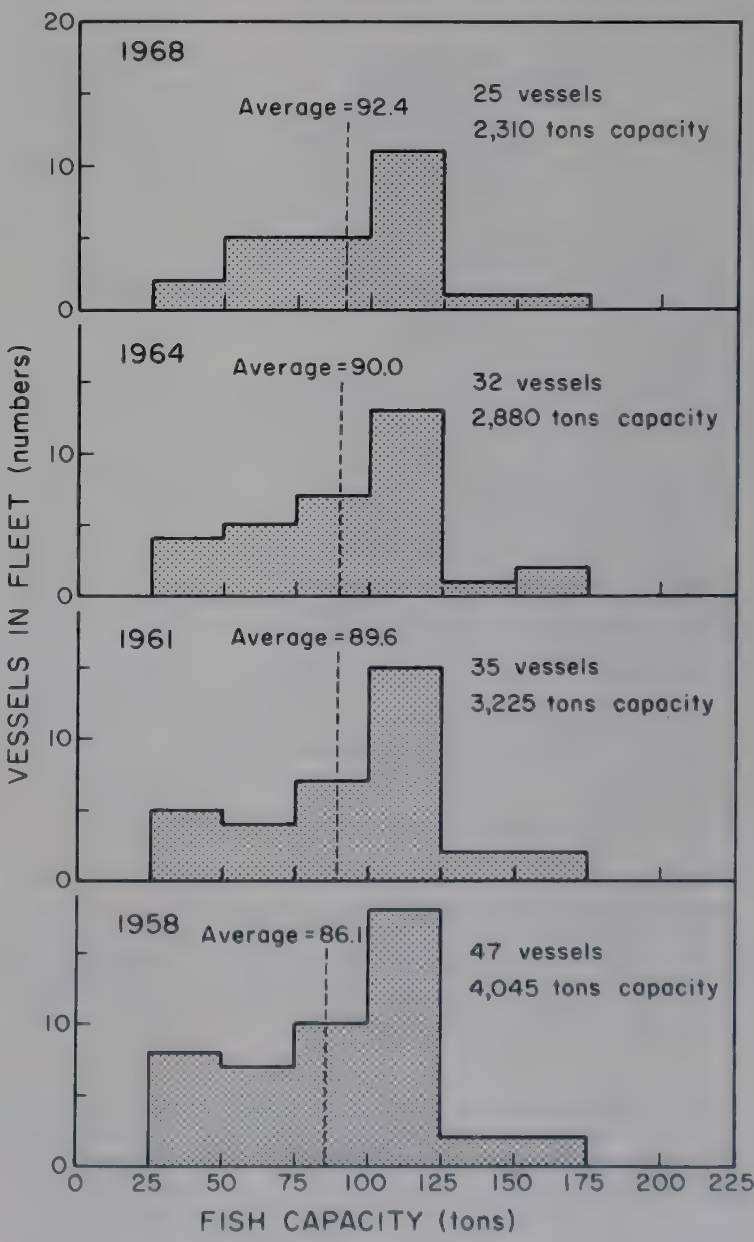


Figure 2.—San Pedro wetfish-boat fleet, 1958-68. (Fishermen's Cooperative Association of San Pedro furnished these data.)

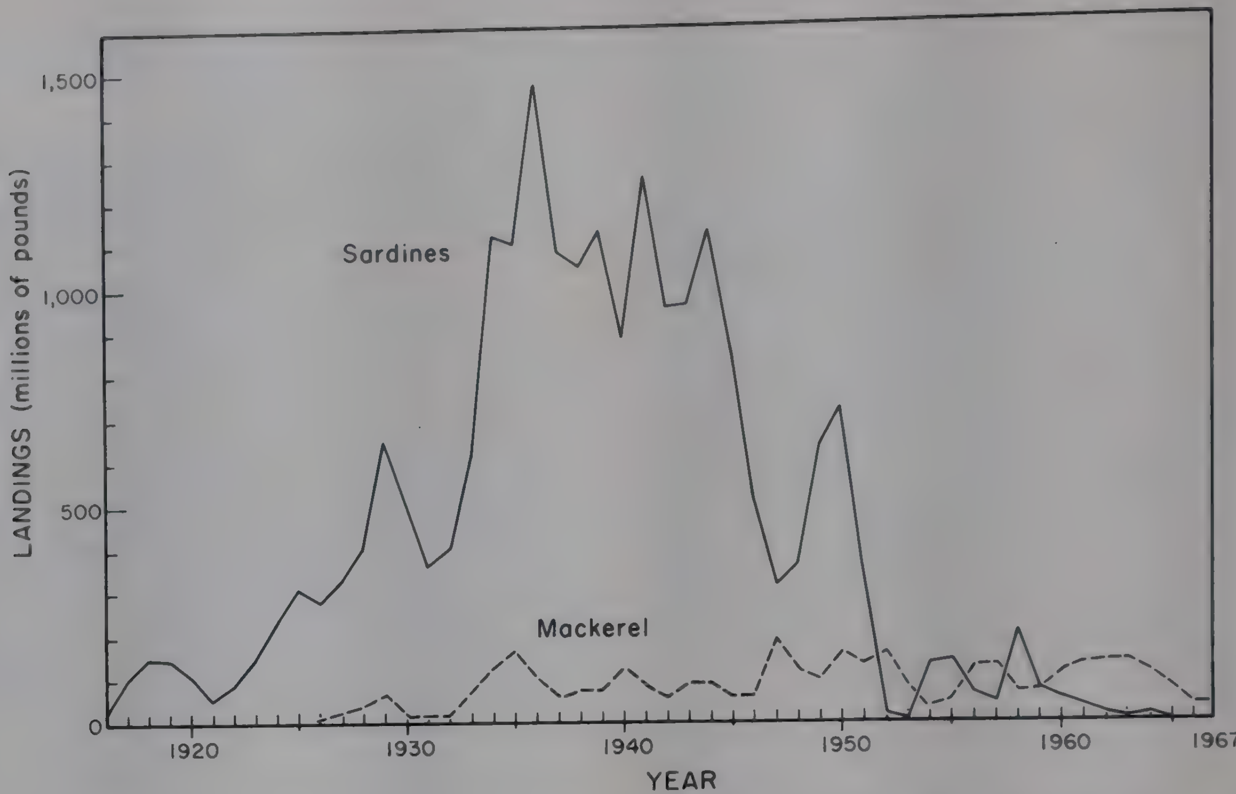


Figure 3.—Sardine and mackerel landings in California, 1916-67. The data are from the California Division of Fish and Game, Staff, Bureau of Marine Fisheries, 1949; California Department of Fish and Game, Staff, Marine Fisheries Branch, 1954, 1956; California Department of Fish and Game, Staff, Marine Resources Operation, 1958; California Department of Fish and Game, Biostatistical Section, Marine Resources Operation, 1960a, 1960b, 1961, 1963, 1964, 1965; Greenhood and Mackett, 1965, 1967; and Heimann and Frey, 1968a, 1968b.

albacore, bluefin and skipjack tuna, and bonito, which they had fished less intensively while sardines were abundant. The main emphasis was on mackerel (both species). They joined a declining fleet of various types of less efficient vessels already fishing primarily for Pacific mackerel (Croker, 1938; Roedel, 1952). When sardines in some years became temporarily more abundant, the vessels fished that species for short periods, so that landings of sardines and mackerel showed an inverse relation between 1952 and 1962 (Figure 3). Because landings of sardines have been negligible since 1962, the fleet has depended primarily on mackerel. Thus, the wetfish-boat fleet is essentially what is left of the sardine fleet. The newest boat in the fleet was built in 1947 (Table 1).

Table 2 shows the landings of the wetfish boats at San Pedro during 1963 through 1967. It also shows the percentage of the total landings in California for each species making up the San Pedro wetfish-boat landings.[2] During this period, landings for the fleet closely paralleled the total landings for California (Figure 4). Because the species landed vary widely in exvessel price (Table 3), figures for landings alone do not illustrate the species base of the fleet in value terms. Figure 5 shows the makeup of the landings in terms of the percentage of total value accounted for by each species during 1963 to 1967.[3] The year-to-year varia-

Table 1.—Year of construction of 24 boats that were in the San Pedro wetfish-boat fleet in 1968

Year of construction	Vessels
	Number
1935	4
1937	5
1939	3
1940	1
1944	8
1945	1
1946	1
1947	1
Total	24

Source: U.S. Bureau of Customs (1965) and information provided by the Fishermen's Cooperative Association of San Pedro.

[2] From unpublished data furnished by the California Department of Fish and Game.
[3] From unpublished landings data furnished by the California Department of Fish and Game and from price data gathered in the present study.

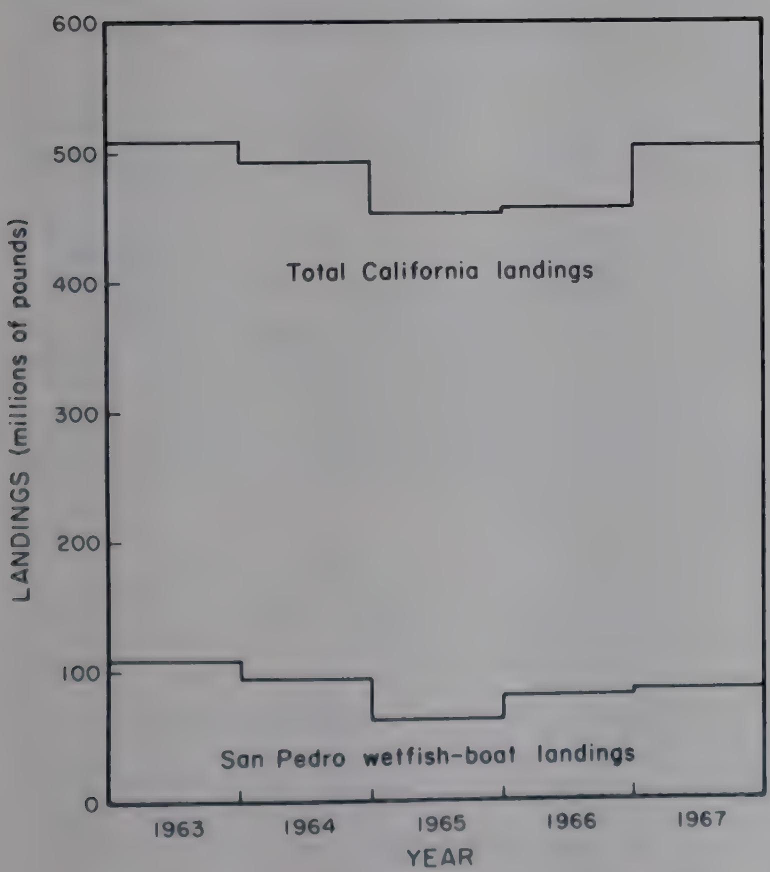
Table 2.—Landings of the San Pedro wetfish-boat fleet, 1963-67[1] (with percent of total California landings in parentheses[2])

Species	Landings in:				
	1963	1964	1965	1966	1967
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Jack mackerel ...	68,783,000 (72.1)	60,325,000 (69.6)	47,523,000 (71.1)	31,044,000 (76.0)	29,447,000 (77.1)
Pacific mackerel ...	29,595,000 (73.5)	21,539,000 (80.3)	4,566,000 (64.8)	2,612,000 (56.4)	632,000 (54.2)
Sardine	3,538,000 (49.6)	8,270,000 (63.0)	1,110,000 (57.6)	406,000 (46.2)	40,000 (26.8)
Bluefin tuna	3,295,000 (10.9)	2,938,000 (12.7)	2,220,000 (13.9)	1,727,000 (5.0)	1,585,000 (11.5)
Albacore tuna ...	375,000 (0.8)	21,000 (0.1)	694,000 (3.0)	87,000 (4.8)	1,000 (<0.1)
Bonito	2,606,000 (64.8)	1,674,000 (64.1)	4,019,000 (71.3)	13,412,000 (70.0)	12,314,000 (58.0)
Anchovy	1,000 (<0.1)	170,000 (3.4)	212,000 (3.7)	30,122,000 (48.4)	37,342,000 (53.6)
Other[3]	83,000	369,000	351,000	299,000	236,000
Total	108,966,000 (21.4)	95,602,000 (19.4)	62,062,000 (13.7)	80,523,000 (17.6)	81,777,000 (16.2)

[1] The data on landings of the San Pedro wetfish-boat fleet are from unpublished data furnished by the California Department of Fish and Game.
[2] The total California landings from which the percentages were calculated are from the California Department of Fish and Game, Biostatistical Section, Marine Resources Operations, 1965; Greenhood and Mackett, 1965, 1967; Heimann and Frey, 1968a, 1968b.
[3] The other species include: skipjack tuna, "bullet mackerel" *(Auxis thazard)*, Pacific pompano *(Peprilus simillimus)*, blacksmith *(Chromis punctipinnis)*, "smelt" (Atherinidae), halfmoon *(Medialuna californiensis)*, "perch" *(Embiotocidae)*, white croaker *(Genyonemus lineatus)*, white seabass *(Cynoscion nobilis)*, "shark," squid *(Loligo opalescens)*, and small quantities (less than 2,000 pounds) of several other species.

tions in the composition of the catch reflect the following changing conditions in the fishery:

1. The decreasing population of Pacific mackerel, due to overfishing (Ahlstrom, 1968).



2. Yearly fluctuations in the abundance of the migratory bluefin tuna and albacore, probably due to varying local oceanographic conditions within the range of the wetfish fleet.
3. Yearly fluctuations in the demand for bonito by the processors.
4. A legal moratorium on sardine fishing (as of 1967), following a drastic decline in abundance.
5. The legalization by the California State legislature of the taking of anchovies for reduction to fish meal (as of November 1965).

Although these data and observations indicate that the San Pedro wetfish industry is not in a strong position economically, they do

Figure 4.—San Pedro wetfish-boat landings and total California landings, 1963-67. The total-landing data are from the California Department of Fish and Game, Biostatistical Section, Marine Resources Operation, 1965; Greenhood and Mackett, 1965, 1967; Heimann and Frey, 1968a, 1968b. The wetfish-boat landings are from unpublished data furnished by the California Department of Fish and Game.

Table 3.—Average prices paid for fish taken by San Pedro wetfish boats, 1963-68

Species	Prices in:											
	1963		1964		1965		1966		1967		1968[1]	
	Cents per pound	*Dollars per short ton*	*Cents per pound*	*Dollars per short ton*	*Cents per pound*	*Dollars per short ton*	*Cents per pound*	*Dollars per short ton*	*Cents per pound*	*Dollars per short ton*	*Cents per pound*	*Dollars per short ton*
Mackerel (both spp.)[2]	2.103	42.0[illegible]	2.294	45.88	2.713	54.26	3.430	68.60	3.625	72.50	3.771	65.42
Sardine[3]	3.307	66.14	3.261	65.22	3.234	64.68	18.649	[3]372.98	20.000	[3]400.00	--	--[4]
Bluefin tuna[2]	10.212	204.24	11.114	228.28	13.135	262.68	14.484	289.68	12.396	247.92	--	--[4]
Albacore tuna[2]	16.190	323.80	15.944	318.62	16.081	321.62	24.738	494.76	19.500	390.00	--	--[4]
Skipjack tuna[2]	9.976	199.52	--	--[5]	10.240	204.80	--	--[5]	--	--[5]	--	--[4]
Bonito[3]	2.870	57.40	2.629	52.58	2.780	55.60	4.067	81.34	4.146	82.92	4.248	84.96
Anchovy	1.698	[5]33.96	1.649	[6]32.66	1.723	[6]34.66	0.941	18.82	1.000	[2]20.00	--	--[4]
Average for all species	2.465		2.665		3.300		2.948		2.679		--	

[1] First quarter of 1968.
[2] Based on settlement data gathered in the present study (see section on data base, page 112).
[3] Sold mostly to fresh-fish markets.
[4] No fish were landed in the first quarter of 1968.
[5] Negligible quantities of skipjack were caught in these years by the wetfish fleet.
[6] Based on landings and value data; California Department of Fish and Game, Biostatistical Section, Marine Resources Operations, 1965; Greenwood and Mackett, 1965, 1967.

not supply sufficient information for a complete analysis. The purpose of the work reported here therefore was to gain a complete view by means of a detailed economic study. The main specific aims of this study were:

1. To determine the condition of the wetfish-boat fleet at San Pedro (as of March 1968) with respect to (a) productivity, revenue, and profits of the fleet, (b) capital structure and return on investment, (c) crew earnings, and (d) employment.

2. To present a model with which prospective wetfish-boat operators may predict costs and earnings under varying conditions of such factors as composition of the catch, characteristics of the vessel, value of the vessel, and size of the crew.

3. Then, using the model developed and examining other pertinent economic data, to determine the economic feasibility of constructing new wetfish boats and of expanding the fleet.

An understanding of the data in this report and of the discussion of the data requires an understanding of share-out procedures--that is, of the way in which the proceeds of the catch are divided between owner and crew. A discussion of these procedures therefore follows.

A share-out, or "settlement," is made by the boat owner when enough fish have been sold to more than cover expenses, usually once a month at the end of the "dark" (of the moon). Because the lunar month is 29½ days, sometimes more than one settlement occurs in a calendar month. A settlement usually is not made, however, when insufficient fish are caught to cover operating expenses during the lunar month. In this event, income and expenses are held over until the next or a later period. Occasionally, a settlement may be made even when expenses are not met, and negative "shares" are computed and deducted from the shares in the following settlement.

The settlement is computed on a "settlement sheet" having a standard format. Copies of the settlement sheet are retained by the boat owner and his accountant, and a copy is forwarded to the labor union representing the crew. Computing the settlement involves four steps as follows:

1. Operating costs or "trip expenses" are deducted from the gross revenue. By union agreement, only certain items of expense may be deducted from the gross. These deductible items include fuel; lubricating oil; salt; ice; foreign fishing licenses; explosives and rifle ammuni-

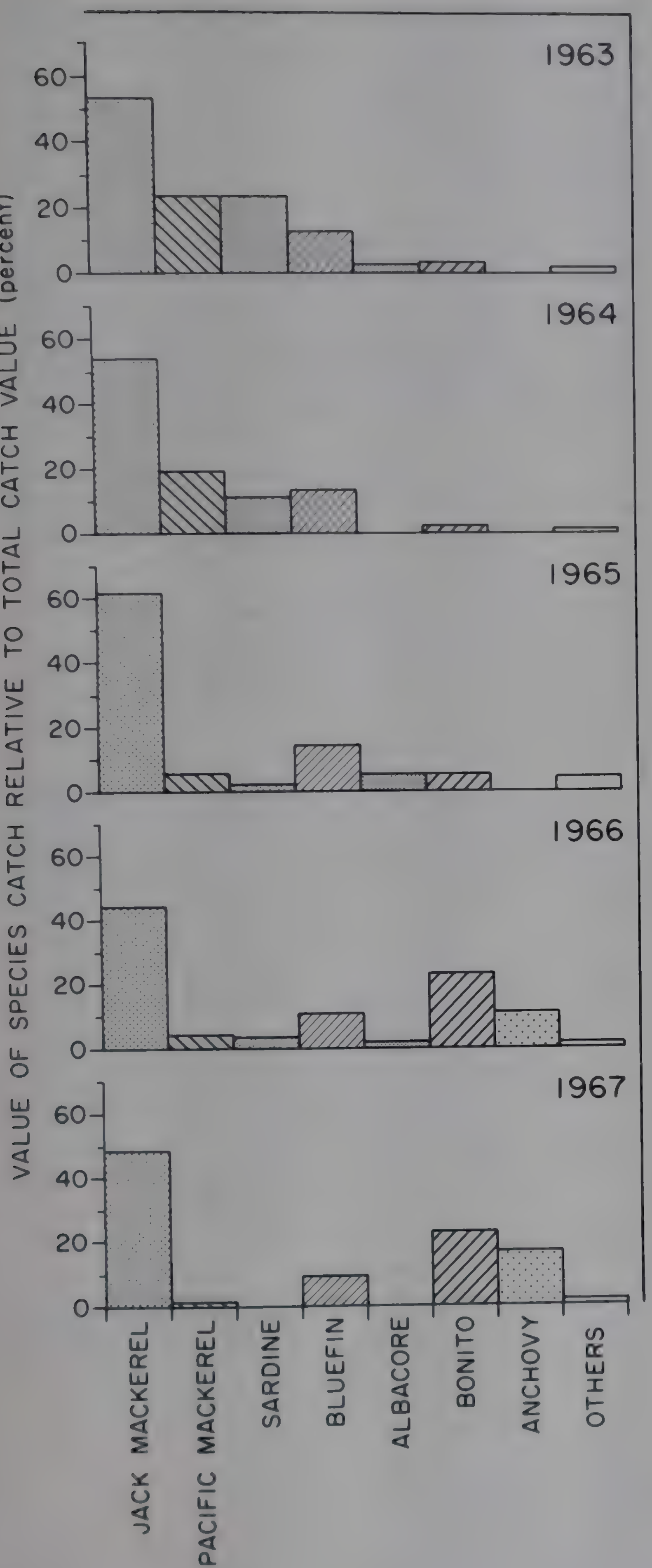


Figure 5.—Species makeup by value of catch of San Pedro wetfish-boat fleet, 1963-67. The figures are based on unpublished landings data furnished by the California Department of Fish and Game.

tion for control of seals and sharks; airplane spotting services; and contributions to the welfare fund, the pension fund, and the patrol agency.

The patrol agency is maintained by the union members. Its duties are to police the collective bargaining agreement and to check weights and payments.

Other expense items formerly deducted from the gross but not allowable under present agreements included: lobbying, attorneys' fees, donations, appliances, and rental and repairs of electronic equipment. Only the last item appeared frequently on settlement sheets included in the sample used in the present study.

The gross revenue as construed here excludes the value of rejected fish, overlimits (fish not authorized to be delivered to plants but delivered nevertheless), and fish transferred to other vessels, but it does include the value of fish transferred from other vessels.

2. The net proceeds (gross income minus trip expenses) are divided into the boat share and the gross crew share. The division is made according to a schedule established by agreement with the labor unions (Table 4). When refrigeration equipment is used, the vessel receives an additional 3 percent of the net proceeds.

Table 4.—Share-out schedule for San Pedro wetfish boats

Boat's hatch capacity	Boat's share	Crew's share	Members in crew including skipper
Tons	*Percent*	*Percent*	*Number*
1- 25	34¾	65¼	5- 6
26- 50	36½	63½	6- 7
51- 75	37½	62½	9-10
76-100	39	61	10-11
101-125	39½	60½	10-11
126-150	41½	58½	11-12
151 and up	42½	57½	11-12

Source: Fishermen's Cooperative Association of San Pedro.

3. The crew's gross share is split equally among the members of the crew, including any owners who serve as crew mem-

bers. If a crewman was not on the boat for the entire fishing period, his share is prorated accordingly. This prorating is done by making a "split"--that is, by computing separate settlements for the segments of the period in which the size of the crew was different. For example, if 10 men worked for 14 days and 11 men worked for an additional 12 days, a separate settlement is computed for 14 days with 10 shares and for 12 days with 11 shares. Fuel, welfare, pension, electronics, and most "other trip expenses" are prorated to the segments. Patrol and airplane spotting costs are deducted from the gross for the segment in which these costs occurred. Likewise, catch income belongs to the segment during which the fish were caught. For this report, we use the average size of crew to the nearest whole man during the month.

4. The cost of provisions and of galley supplies such as crockery and cooking utensils is split equally among the members of the crew and is deducted from their shares.

Data for this report were obtained primarily from records maintained by bookkeeping and accounting firms for the vessel owners. These records include: (1) copies of the settlement sheets together with copies of receipts for fish sold to wholesalers or processors during the period covered by each settlement and (2) balance sheets, profit-and-loss statements, tax forms, and other documents pertaining to the finances of the corporation or partnership operating the vessel.

Access was not gained to the company records of some vessels. For these vessels, we obtained settlement information from the copies of settlement sheets retained by the unions, but we could get neither catch nor corporation financial data.

Marine Resources Operations of the California Department of Fish and Game furnished data on total landings by the wetfishboat fleet.

To obtain estimates of costs of constructing new vessels, we interviewed shipbuilders directly. County tax records gave us market values of vessels in the existing fleet. Marine insurance agents provided information on insurance rates.

As was just indicated, complete data could not be obtained. Consequently, we base this report on sample data. The sizes of the samples for (1) the annual financial data, (2) the costs and earnings data for monthly settlements, and (3) the catch data were as follows:

(1) <u>Annual financial data.</u> The sample included annual data on finances for 12 vessels from 1963 to 1965 inclusive, for 14 vessels for 1966, and for 15 vessels for 1967. These data represented about 44 percent of the total vessel years for the fleet during the period. The data were not strictly comparable on a time axis because the fiscal year used varied from company to company.

(2) <u>Revenue and costs data for monthly settlements.</u> We obtained access to monthly settlement sheets for 22 vessels. The sample included data on revenue, itemized trip expenses, and crew size from 940 settlements from January 1963 to March 1968, inclusive (Table 5). Three vessels entered the sample in 1965 and one in 1966; the other 18 vessels were covered for the entire period. Each vessel was not represented by a settlement for each month during the sample period, because of tieups due to repairs, modifications, and

Table 5.—Sample size of revenue and costs data for monthly settlements, 1963-68

Year	Settlements in sample	Vessels in sample	Revenue in sample	Revenue relative to total revenue for fleet
	Number	*Number*	*Dollars*	*Percent*
1963	169	18	1,413,000	52.4
1964	163	18	1,394,000	54.7
1965	174	21	1,499,000	73.2
1966	194	22	1,796,000	75.6
1967	188	22	1,726,000	78.8
1968[1]	52	22	346,000	--

Note: The data on total revenue and estimates are based on unpublished landings data furnished by the California Department of Fish and Game and on price data from the present study.
[1] Data for only the first quarter of the year.

labor disputes and because catches in some months were too small to justify settlement. The settlements in the sample represent from

52.4 percent (1963) to 78.8 percent (1967) of the total revenue of the wetfish-boat fleet (Table 5).

(3) Catch data. We gathered data on species, weight, and price of the catch for 826 settlements for 18 of the 22 vessels for which we had obtained cost and revenue data. For the remaining four vessels, catch data correlated with settlements were not available. Table 6 shows the percentage in the sample of the total wetfish-boat fleet landings for each major species. Pacific mackerel and jack mackerel were combined into a single category, "mackerel," because many of the cannery receipts used as the sources of data in this study did not specify the species of mackerel. The sample is skewed toward tuna and away from sardines, anchovies, and bonito for most of the years. This bias for the higher priced species is also reflected in a comparison of the elements of the last column of Table 5 with those of the last row of Table 6. For example, the sample for 1963 includes 38.2 percent of the total fleet landings but it includes 52.4 percent of the value of the landings. This skewness must be taken into account when an empirical costs-prediction model is constructed on the basis of the present sample.

Table 6.—San Pedro wetfish-boat landings included in sample by species, 1963-67

Species	Landings included in the sample relative to the total wetfish landings in:				
	1963	1964	1965	1966	1967
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Mackerels	44.4	46.9	58.0	62.4	71.2
Sardine	20.2	42.9	22.3	10.0	5.5
Bluefin tuna	68.0	63.0	73.0	74.1	60.1
Albacore	67.1	--	57.3	71.4	--
Bonito	30.0	30.9	19.2	55.5	60.7
Anchovy	--	0.0	0.0	41.1	65.1
Average	38.2	38.9	38.3	52.4	54.8

Note: Where no data are given, the landings of the given species were negligible (see Table 7).

A portion of the catch in the sample for each year was classified as "other or unidentified (single price paid for a mixed catch, or itemized cannery receipt not available)." Table 7 shows the percentage of the value of the landings in the sample classified in this category for each year. We do not know the proportion of this value that should pertain to each species. We therefore were not provided with a basis for increasing the percentage by weight listed as included in the sample (Table 6). A decreasing percentage for sardines in Table 6, however, is almost certainly due in part to the fact that a greater percentage of the total landings of sardines in southern California are from mixed catches of mackerel and sardines (Greenhood, 1965). The composition of these mixed catches was estimated in the landings data furnished by the California Department of Fish and Game but not on the cannery receipts that were the sources of catch data for this study.

Table 7.—Relative value of landings classified as "other or unidentified," 1963-68

Sample year	Relative value of landings classified as "other or unidentified"
	Percent
1963	2.4
1964	10.1
1965	8.3
1966	4.0
1967	6.9
1968[1]	1.1

[1] First quarter.

I. FINANCIAL CONDITION OF THE FLEET

In our evaluation of the financial condition of the fleet, we consider the following factors: (A) productivity, revenue, and profits, (B) capital structure and return on investment, (C) crew earnings, and (D) employment.

A. PRODUCTIVITY, REVENUE, AND PROFITS

Productivity per vessel in terms of tons of fish landed showed no net gain from 1963 to 1967 (Table 8). Landings per vessel in 1967

Table 8.—Productivity of San Pedro wetfish-boat fleet, 1963-67

Year	Average landings per vessel	Average revenue per vessel	Total revenue of fleet
	Tons	*Dollars*	*Dollars*
1963	1,473	73,000	2,697,000
1964	1,366	73,000	2,549,000
1965	872	57,000	2,048,000
1966	1,184	70,000	2,375,000
1967	1,461	78,000	2,191,000

Note: These figures are based on unpublished data on landings furnished by the California Department of Fish and Game and on the price data in Table 3.

ranged from 535 to 2,570 tons (Figure 6). The average vessel revenue showed a net increase, but the total fleet revenue decreased owing to the decrease in the number of vessels. The vessel average annual revenue for the period ranged from $45,145 to $119,610 with the grand average being $77,557 (Figure 7).

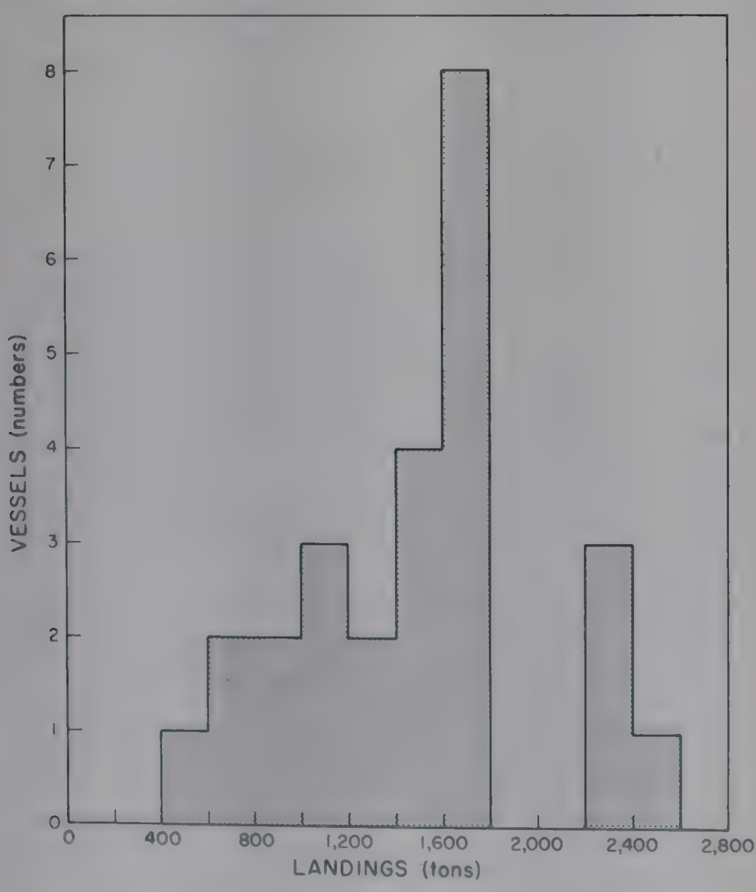


Figure 6.—Frequency distribution of total landings per vessel for 1967 by San Pedro wetfish boats. This graph is based on unpublished landings data furnished by the California Department of Fish and Game.

For this analysis, profits (or losses) shown in Profit and Loss Statements have been adjusted by adding salaries paid to officers of the corporations. Wages, commissions, and bonuses paid to these officers for serving as crew members are part of the corporation's operating costs (included in crew wages). Salaries in general were a form of draws on account of future profits, but in some situations part of these salaries might be considered as managerial cost. Since, from the records made available, it was not possible to separate these two types of payments, all salaries paid to officers were added to profits. With these adjustments, the average values of gross profit (before taxes) for the whole fleet ranged from $5,100 per vessel in 1963 to $10,726 in 1966 (Table 9A). Although some vessels showed losses as the end result of their operations, most closed each year with a profit. Of 65 vessel-years analyzed, 51 (or 78.5 percent) were profitable.

The two subgroups of vessels from Table 9A are further characterized by the range of profits or losses in each year and by the quartile values of profits. Table 9B shows the range of profits, as well as the range of losses. In general, the median values (Q_2 in Table 9C) are lower than are the mean values shown in Table 9A.

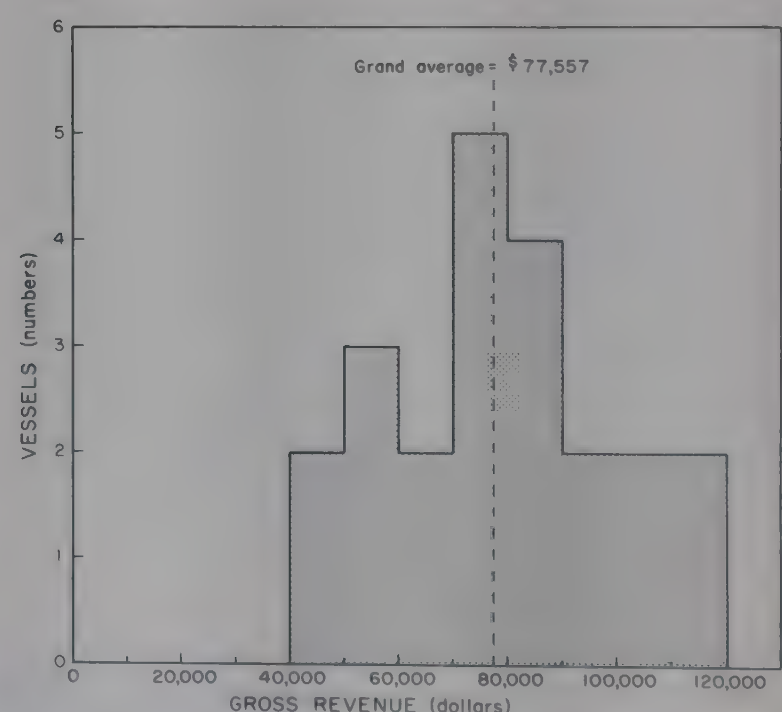


Figure 7.—Frequency distribution of average annual gross revenue per vessel from 1963 to 1967. The graph is based on settlement data. The averages for four vessels that entered the sample after 1963 were adjusted on the basis of the assumption that their efficiencies relative to the other vessels were the same before and while they were in the sample.

Table 9A.—Average values of gross revenue and profit (or loss) per vessel, 1963-67

Year	Data for: All vessels			Profitable vessels			Nonprofitable vessels		
	Vessels	Gross revenue	Profit before taxes	Vessels	Gross revenue	Profit before taxes	Vessels	Gross revenue	Profit before taxes
	Number	*Dollars*	*Dollars*	*Number*	*Dollars*	*Dollars*	*Number*	*Dollars*	*Dollars*
1963	12	77,770	5,100	9	84,893	7,706	3	56,400	—2,719
1964	12	76,072	7,600	11	77,710	8,504	1	58,058	—2,355
1965	12	76,847	5,660	10	82,671	7,191	2	47,726	—1,992
1966	14	98,105	10,726	12	103,950	13,329	2	63,034	—4,888
1967	15	78,110	5,104	9	91,113	10,577	6	58,604	—3,106

Note: These figures are based on data from profit and loss statements.

Table 9B.—Range of profits on profitable vessels and of losses on unprofitable vessels, 1963-67

Year	Range of profits	Range of losses
	Dollars	*Dollars*
1963	1,416 - 14,570	803 - 3,737
1964	1,453 - 27,568	(See note)
1965	2,291 - 17,641	1,072 - 2,912
1966	1,869 - 39,558	415 - 9,361
1967	1,366 - 33,741	210 - 6,524

Note: In 1964, only one vessel closed the year with a loss.

A regression of profit on gross revenue (Figure 8) shows that the breakeven point for a vessel in the fleet in 1967 was about $70,000 gross revenue. In that year, gross revenue ranged to over $150,000.

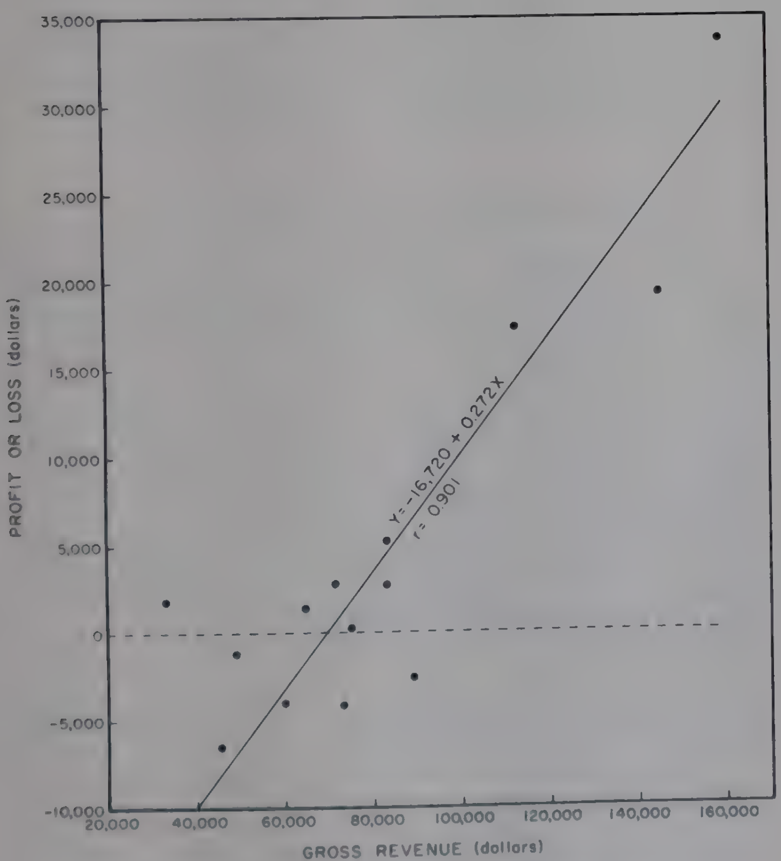


Figure 8.—Relation between profit or loss and gross revenue for 14 San Pedro wetfish boats in 1967. This plot is based on profit and loss statements.

Table 9C.—Quartile values of profits, 1963-67

Year	Profits in quartile: Q_1	Q_2	Q_3
	Dollars	*Dollars*	*Dollars*
1963	6,256	7,067	10,551
1964	2,180	6,708	11,534
1965	2,712	4,894	12,310
1966	3,971	8,249	31,159
1967	2,281	5,248	18,341

B. CAPITAL STRUCTURE AND RETURN ON INVESTMENT

The 1967 balance sheets for 15 vessels showed total assets of $476,700 or $31,780 per vessel. The assets for individual vessels ranged from $4,679 to $63,844. On the average, 82.8 percent of the total assets were made up of fixed assets--that is, of the depreciated value of the vessels and equipment. Current assets (cash in the bank, accounts receivable, and other) formed the remaining 17.2 percent of the total assets.

The average market value of these vessels as estimated by the Office of Assessor, County of Los Angeles, was about $41,000--that is, it was about 1½ times the book value.

Table 10 shows the sources from which the total assets were financed.

This capital structure reflects rather unfavorable financial conditions in the fleet as a whole. The low amount of quick assets (which in this case is equivalent to current assets) relative to current liabilities, as indicated by a ratio of about 0.5:1, might be a reason for banks to refuse loans. Although a sizable part of total assets (27.4 percent) was financed by stockholders in the form of notes and loans, 51 percent of all notes and

Table 10.—Sources from which the total assets of all wetfish boats and nine of the stronger corporations were financed in 1967

Sources of financing	Amount relative to the total liabilities and capital			
	Assets of all wetfish boats		Assets of nine of the stronger corporations	
	Individual items	Sums	Individual items	Sums
	Percent	*Percent*	*Percent*	*Percent*
Accounts payable	14.32	--	12.06	--
Notes payable	8.25	--	9.38	--
Notes from stockholders	8.99	--	None	--
Total current liabilities	--	31.56	--	21.44
Mortgages and long-term loans	34.93	--	22.20	--
Loans from stockholders	18.40	--	11.36	--
Total long-term liabilities	--	53.33	--	33.56
Capital stock plus accumulated earnings	--	15.11	--	45.00
Total liabilities and capital = assets	--	100.00	--	100.00

long-term liabilities (that is, those over $171,000) came from canneries that receive fish landed by this fleet. This financial dependence on canneries probably puts the vessel owners in a disadvantageous position when they negotiate prices for fish.

The low level of equity capital for the whole group (average 15.1 percent) is effected mainly by six corporations, which show a deficit of $5,000 to $36,000 (average $13,500). Table 10 shows the capital structure for the remaining nine companies.

In this group of nine vessels, current liabilities exceeded current assets by about $2,500 per vessel, indicating a need for working capital. The average equity capital for a vessel in this group was $17,500, whereas fixed assets averaged $34,000 per vessel. The average profit of $8,300 per vessel indicates the following rates of return on investment:

47.4 percent — when related to equity capital,
24.3 percent — when related to fixed assets.

It should be pointed out that the high rate of return on equity capital (47.4 percent) is artificially inflated by abnormal financing practices for these vessels. We observed that a major part of profits is being drawn each year by the corporation's officers in the form of salaries or bonuses. This action leaves the corporations with low equity capital and with no working capital (see previous section).

For a group of five vessels with equity capital ranging from $18,355 to $37,970 the return on investment was 13.3 percent. The median value for this group, $28,162 is used below for predicting the return on investment for old vessels. An actual anticipated value for equity capital should be substituted by a prospective vessel operator.

C. CREW EARNINGS

We calculated the individual crew share for each settlement by dividing the crew share of net proceeds (gross revenue minus trip expenses) by the average number of crewmen (to the nearest whole man) on the vessel during the period covered by the settlement.

1. Fleet Average for 1963-67

The average crewman's earnings in the fleet for each year was calculated by multiplying the average individual crew share per settlement (above) by the average number of settlements per vessel during the year (Table 11). The average crew earnings did not increase during the period, and the real earnings (actual earnings adjusted by consumer price index) decreased 9.2 percent.

2. Vessel Variation in Crew Earnings

The average crewman's annual earnings for each vessel from 1963 through the first quarter of 1968 were calculated in the same manner described earlier and are presented in Table 12. In accordance with the wishes of the vessel owners, we do not identify the

Table 11.–Average crewman's earnings in San Pedro wetfish-boat fleet, 1963-68

Year	Average crewman's share per settlement	Average settlements per vessel	Average crewman's earnings per year[1]	Average crewman's real earnings for year[2]	Sample size	
					Settlements	Vessels
	Dollars	*Number*	*Dollars*	*Dollars*	*Number*	*Number*
1963	438	9.44	4.134	4,134	168	18
1964	440	9.11	4.008	3,953	159	18
1965	445	8.22	3,658	3,551	171	21
1966	493	8.90	4,388	4,140	191	22
1967	480	8.52	4,090	3,752	177	22
1968[3]	324	2.36	--	--	50	22

Note: The fishing season extends over the full calendar year, with an average of about 17 fishing days per month.
[1] The average crewman's earnings per year includes nontaxable provisions, which averaged $585 per crewman in 1967.
[2] The average crewman's real earnings for the year were adjusted to the 1963 level with consumer price index (Long, 1969).
[3] First quarter.

Table 12.–Average crewman's earnings for San Pedro wetfish boats, 1963-67 and 1968 (1st quarter)

Vessel Number	Average crewman's share per settlement	Average settlements per year	Average crewman's earnings for year
	Dollars	*Number*	*Dollars*
1	353	6.29	2,219
2	358	6.67	2,387
3	292	9.53	2,781
4	322	10.48	3,374
5	352	9.67	3,402
6	366	9.53	3,486
7	414	8.57	3,549
8	400	8.95	3,582
9	359	10.29	3,692
10	420	8.95	3,761
11	392	9.72	3,809
12	467	8.57	4,004
13	472	8.57	4,047
14	467	8.76	4,171
15	457	9.14	4,179
16	537	8.57	4,601
17	486	9.91	4,814
18	534	9.53	5,086
19	582	8.95	5,211
20	580	10.27	5,957
21	735	8.95	6,581
22	591	11.36	6,716
Grand average	453	9.15	4,164

Note: These figures are based on settlement data. For vessels entering the sample after 1963, the crewman's earnings for the year were adjusted to the 1963 level with the consumer price index (Long, 1969).

estimates by vessel. Figure 9 presents the frequency distribution of the estimates in $500 intervals. The variation in crew earnings has two major components--namely, (1) the variation in the crewman's share per settlement and (2) the variation in the number of settlements per year. The latter variation is not amenable to analysis, because it is determined by (1) different response to labor disputes by management, (2) different tieup periods for gear and vessel modification and repairs, and (3) different fishing success. The factors affecting crewman's share per settlement, the

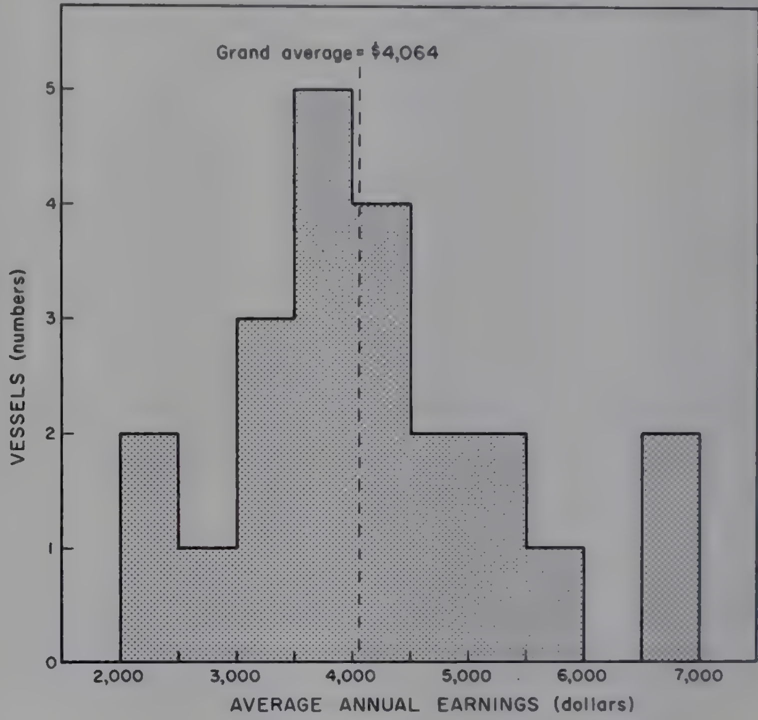


Figure 9.–Frequency distribution of crewman's average annual earnings 1963-67. The graph is based on settlement data.

other source of variation, are examined later in the section on predicting earnings.

D. EMPLOYMENT

The size of crew on the vessels (Table 13) as well as the number of vessels in the fleet

Table 13.–Average size of crew in the San Pedro wetfish-boat fleet, 1963-68

Year	Men in crew
	Number
1963	10.29
1964	10.28
1965	9.94
1966	9.65
1967	9.74
1968[1]	9.52

Note: These figures are based on settlement data.
[1] First quarter.

decreased during 1963 to 1967. The combined effect of these two factors was a 30-percent decrease in the number of full-time jobs (Figure 10) from about 381 jobs in 1963 to 238 in 1968. These estimated totals do not include employment in other phases of the wetfish industry, such as processing, maintenance of vessels, and supply.

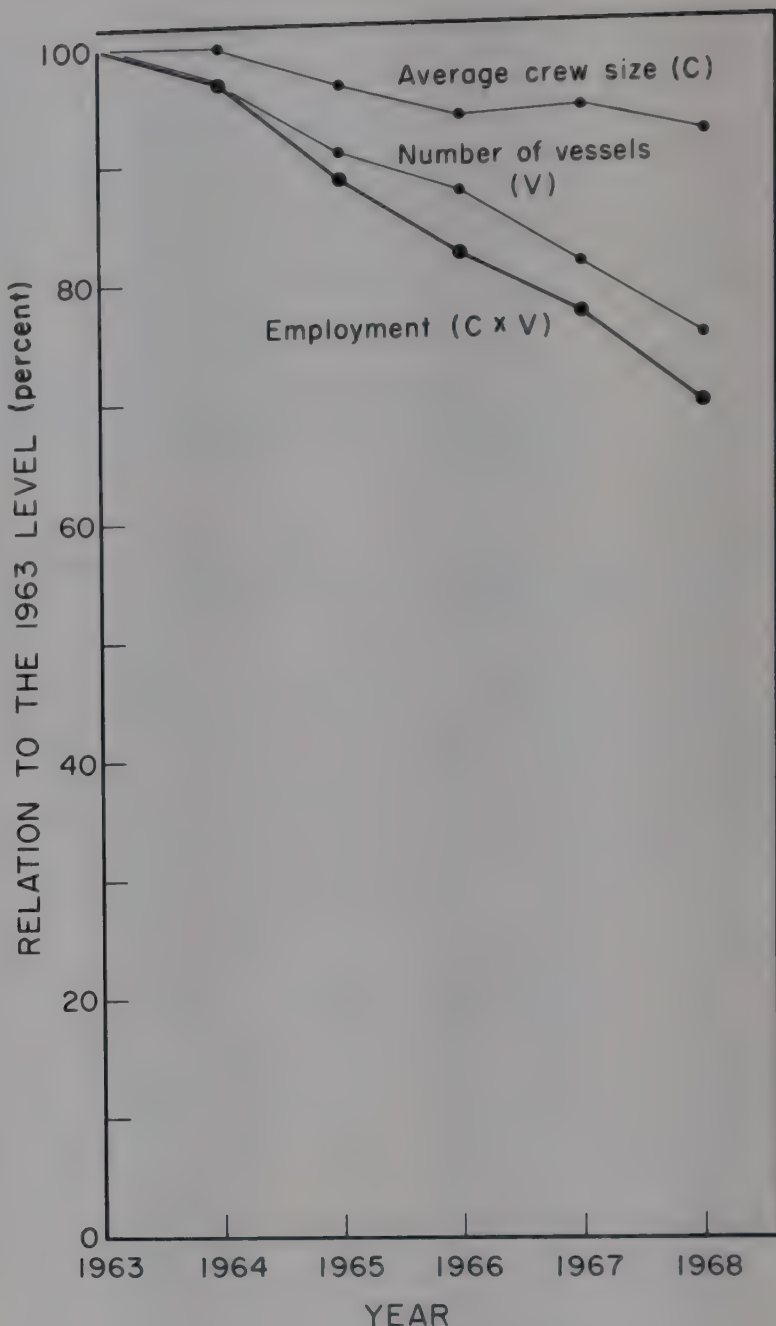


Figure 10.—Combined effect of decreasing size of fleet and decreasing size of crew on employment in the San Pedro wetfish-boat fleet, 1963-68. This graph is based on Figure 2 and Table 12.

II. COSTS AND EARNINGS MODEL

Having examined the financial condition of the fleet, we turn now to the costs and earnings model. We first analyze costs and then predict earnings.

A. ANALYSIS OF COSTS

Average total costs per vessel (operating costs or "trip expense" and owner's costs; crew's share not deducted) reached a high in 1966 (Table 14) and then decreased in 1967. The ratio of costs to value (total costs divided by the value of the catch) increased to a high in 1965 and then decreased (coincidentally with the advent of the anchovy fishery) to below the 1963 level.

Table 14.—Average total costs per vessel (operating costs + owner's costs exclusive of the payments to the crew on "crew's share") for San Pedro wetfish boats, 1963-67

Year	Total costs	Ratio of cost to value of catch
	Dollars	
1963	31,547	0.432
1964	31,549	.432
1965	31,022	.544
1966	37,394	.534
1967	32,882	.422

Note: These figures are based on settlement data and annual financial data.

Operating costs and owner's costs are discussed separately in the following section, and a submodel is developed for each cost category.

1. Operating Costs

The owner and the crew share operating costs or "trip expenses" (described in section on share-out procedures above). Two major items of costs are fuel and airplane spotting services. The price of diesel fuel in 1968 was 14.5 cents per gallon. When airplane spotting is used, 5 percent of the value of the catch goes to the spotter. Welfare and other fund contributions are calculated as a percentage of gross revenue or as a charge per ton of fish landed. Other costs are related to the time spent at sea and to the size of the main engine, and still others include expenses trat are incurred sporadically and that have no relation either to the time spent at sea or to the proceeds from fishing.

Average operating costs per vessel remained almost constant during 1963 to 1967 (Table 15). Costs per pound of fish landed increased to a high in 1965 and then decreased when anchovies entered the landings.

Table 15.–Average operating costs per vessel and per pound of fish landed by the San Pedro wetfish-boat fleet, 1963-67

Year	Operating costs	
	Dollars per vessel	*Cents per pound of fish landed*
1963	10,317	0.363
1964	10,597	.378
1965	9,990	.499
1966	10,341	.412
1967	10,027	.396

Note: These figures are based on settlement data.

The multispecies makeup of the catch of the San Pedro wetfish fleet demands that operating costs be examined for varying compositions of catch. This requirement becomes even more important when we recognize that a future expanded wetfish fleet will perhaps have to depend more on low-priced fish--that is, on anchovies--and less on high-priced fish--that is, on tuna--than does the present fleet. Because two or more species are usually landed by each vessel during any given settlement period, operating costs could not be related directly to species. A multiple regression analysis based on monthly settlement data for 1967, however, indicated that a significant linear correlation exists between the amount of operating expenses (dependent variable) and landings of mackerel, tuna, bonito, and anchovies (independent variables). The regression is of the form:

$$\hat{Y} = 914 + 0.00103X_1 + 0.00519X_2 + 0.00399X_3 + 0.00038X_4$$

where $\hat{Y}$ = operating costs, in dollars
X_1 = pounds of mackerel (jack and Pacific) landed
X_2 = pounds of tuna (bluefin, albacore, and skipjack) landed
X_3 = pounds of bonito landed
X_4 = pounds of anchovies landed

(t_b, in order, = 4.63, 3.33, 11.91, 3.78; $p<0.001$, R_2 = 0.75)

The differences in operating-costs coefficients between species reflect species differences in schooling behavior and in geographical distribution. Tuna are caught a few tons at a time, but a vessel may be loaded with anchovies in two sets of the net. Although jack mackerel are often caught as far as 50 to 100 miles from port, anchovies are usually caught within 10 miles of port.

A statistically significant and positive relation was found between operating costs and the horsepower of the main engine (in the range of 150 to 335 horsepower), but the maximum effect on predicted costs at $150,000 gross revenue for the present fleet was only $132; consequently, the variable was dropped from the equation. Capacity of the vessel was found to be of low significance (t_b = 1.67), therefore that variable was also dropped from the regression.

Figure 11 shows the fit of predicted annual operating costs to actual operating costs for 15 vessels in 1967. To obtain the annual estimates, we multiplied the Y-intercept of the regression equation times the number of settlements made during 1967 and multiplied the coefficients times the landings of the four species.[4]

[4] California Department of Fish and Game furnished the landings data.

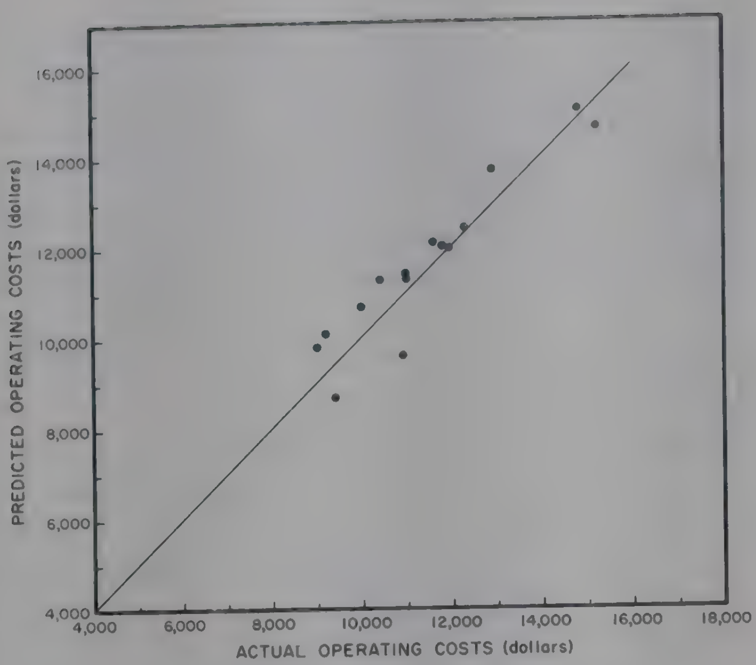


Figure 11.—Fit of operating costs model to actual operating costs. The curve is a 45° line (slope = 1, correlation coefficient = 1) along which the points would lie if the model were a perfect fit.

Using the prices of fish in 1967, we can rewrite the operating costs relation in terms of cost per dollar's worth of fish landed annually:

$$\hat{Y} = 8{,}052 + 0.0275X_1 + 0.0419X_2 + 0.0939X_3 + 0.0380X_4 \qquad \text{(Equation 1)}$$

where $\hat{Y}$ = predicted annual operating costs, in dollars
X_1 = value of mackerel landings, in dollars
X_2 = value of tuna landings, in dollars
X_3 = value of bonito landings, in dollars
X_4 = value of anchovy landings, in dollars

We obtained the value $8,052 by multiplying the Y-intercept for the monthly operations cost regression times 8.81, the average number of settlements per year for the fleet during 1963 to 1967. If no strikes, layups for repairs, or very slack fishing months are anticipated, the value $10,968 (12 months multiplied by $914 per month, the Y-intercept for the monthly operating costs regression) should be used as the constant. According to this relation, the maximum predicted effect of species composition of landings on annual operating costs at a gross-revenue level of $150,000 (arbitrarily chosen) is the difference between the predicted cost for an all-mackerel catch and that for an all-bonito catch, or $9,960.

2. Owner Costs

Owner costs are those deducted from the owner's share of the net proceeds and are categorized here under (a) parts and repairs, (b) netting and supplies, (c) insurance, (d) payroll taxes, (e) interest on loan, (f) moorage, (g) State and county taxes, (h) depreciation, and (i) a miscellaneous category "office expenses and other costs."

Table 16 presents average values for these costs for the fleet for each year from 1963 to 1967. The purchases of new engines and anchovy nets for many of the vessels in 1966 account for the high values for that year. As a measure of dispersion, we include the coefficient of variation. Methods of estimating owner costs are outlined below. Where appropriate, we use different means of estimation for predicting costs for existing vessels of the type now in the fleet and for hypothetical newly constructed vessels.

Table 16.—Average annual owner's costs per vessel, 1963-67

Source of cost	Costs in:						Coefficient of variation
	1963	1964	1965	1966	1967	1963-67 average	
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Percent*
Parts and repairs	4,664	5,118	4,167	5,398	4,891	4,855	45.6
Netting and supplies	3,158	2,007	2,720	3,842	2,456	2,847	63.1
Insurance	4,472	4,261	4,827	4,971	4,692	4,645	24.8
Payroll taxes	2,954	2,923	2,996	4,329	3,246	3,270	29.7
Interest on loan	463	251	436	790	420	504	121.6
Moorage	513	438	464	431	438	465	30.5
State and county taxes	773	666	607	614	750	688	41.0
Depreciation	2,614	3,004	3,075	4,496	4,410	3,604	61.3
Office expenses and other costs	1,619	2,284	1,740	2,182	1,552	1,873	47.6
Total	21,230	20,952	21,032	27,053	22,855	22,751	19.4

Note: These data were derived from statements of profit and loss.

a. Parts and repairs.—Included in parts and repairs are expenditures for repairs and maintenance, including parts, of the vessel, the seine skiff, and the gear exclusive of the net. The crew furnishes labor for repairs to the net, and the cost of webbing is included under "Netting and Supplies."

(1) Existing vessels.—The vessels are put into drydock once a year on a regular basis for maintenance and insurance inspection. No relation was found between size of vessel, or capacity, and cost of repairs. The great variation in cost of repairs for vessels of similar size is explainable by two factors pointed out by Green and Broadhead (1965) in their study of costs and earnings of tuna seiners. Some owners, especially those of vessels that do relatively poorly on the fishing grounds, habitually postpone upkeep and renovation, and they make only those repairs that are absolutely needed to keep the vessel in operation. Also, some owners with mechanical skills may take care of many of the repairs themselves and may thereby save on labor costs.

A significant relation was found between owner's share in net proceeds and repair costs, perhaps a reflection of the factors mentioned above. The estimating equation is of the form:

$$\hat{Y} = 24 + 0.0787X_2 + 0.0552X_3 \quad \text{(Equation 2)}$$

where $\hat{Y}$ = the costs of repairs in Year t, in dollars
X_2 = the owner's share in the net proceeds in Year t, in dollars
X_3 = the owner's share in the net proceeds in Year (t − 1), in dollars

(t_b in order, 3.92, 2.36; $F = 18.96$ with 2, 41 DF; $r^2 = 0.48$)

(2) New vessels.—Presumably, owners of new seiners will possess adequate working capital and will want to keep their vessels in top condition. We therefore used comparable data on new steel shrimp trawlers, based in ports on the Gulf of Mexico, to estimate the maintenance and repair costs of new wetfish seiners. The sample consisted of 17 shrimp vessels, ranging from 61 to 85 feet registered length (the average was 72 feet). The actual costs for 1967 or 1968 were increased by 20 percent, to account for possible additional maintenance costs on wetfish seiners (such as for power block and refrigeration).

The estimating equation is of the form:

$$\hat{Y} = -17{,}619 + 341.15X \quad \text{(Equation 3)}$$

where $\hat{Y}$ = the maintenance and repair costs, in dollars
X = the registered length of the vessel, in feet

($t_b = 3.12$, $p<0.01$, $r^2 = 0.39$)

b. Netting and supplies.—Netting and supplies include expenditures for net webbing, seine cables, line, hardware, tools, and miscellaneous supply items. Seine cables are replaced about once a year, at a cost of about $500. Worn webbing is replaced every other year on a routine basis, also at a cost of about $500, in addition to that replaced to repair the net when it is torn.

A linear correlation was found between these costs and the quantity of fish landed. The least-squares regression based on data for 1967 is of the following form:

$$\hat{Y} = -240 + 2X \quad \text{(Equation 4)}$$

where $\hat{Y}$ = costs in dollars
X = tons of fish landed

($t_b = 3.77$, $p<0.005$, $r^2 = 0.53$)

This regression indicates that the costs of nets and supplies increase by $2 per ton of fish caught. The addition of the owner's share in proceeds, as a second possible variable in the regression, is not significant statistically.

Insurance.—Insurance is a major expense. Three types of coverage are carried by all boat owners. Hull and machinery insurance covers total loss of the vessel as well as damage caused by fire, stranding, and collision, with a usual deductible amount of $500 per accident. The amount of the insurance premium is based on the market value of the vessel. The seine skiff is covered under this insurance. Net insurance covers full value of the net (depreciated straight line over 5 years, with renovation added to the value) against loss or damage, with a $500 deductible amount for fire only. Protection and indemnity insurance covers illness and injuries of crew members and a broad

range of possible liability to other parties. The usual practice is to insure to \$100,000 for a single claim, with a \$1,000 deductible amount for property liability. Premiums are based on a complex formula that varies with the insurance company and that has to do with such factors as size of crew, age of vessel, and size of vessel. The premiums are about \$2,000 per year for a vessel with a crew of 10.

(1) Existing vessels.—Analysis of costs categorized under "insurance" in the financial reports examined in the present study revealed a variability too great to allow us to estimate insurance costs empirically. This variation is due to differences in coverage and in premium-payment schedules. For purposes of cost prediction, hull and machinery premiums were computed at 6.75 percent of the market value, net insurance premiums were computed at 5 percent of the value of the nets, and protection and liability premiums were computed at \$200 per crewman. In 1968, these premiums provided the coverage described above. Values of vessels and nets are discussed below in the section on depreciation (h).

The equation for insurance costs for existing vessels is as follows:

$$\hat{Y} = 0.0675X_1 + 0.0500X_2 + 200X_3 \quad \text{(Equation 5)}$$

where $\hat{Y}$ = the estimated insurance costs, in dollars
X_1 = the market value of the vessel, in dollars
X_2 = the market value of the nets, in dollars
X_3 = the maximum size of the crew

(2) New vessels.—For new vessels, the cost of hull and machinery insurance is lower than for old vessels. The estimating equation therefore becomes:

$$\hat{Y} = 0.0375X_1 + 0.0500X_2 + 200X_3 \quad \text{(Equation 6)}$$

where $\hat{Y}$ = the estimated insurance costs, in dollars
X_1 = the market value of the vessel, in dollars
X_2 = the market value of the nets, in dollars
X_3 = the maximum size of the crew

d. Payroll taxes.—Social Security taxes are computed as a percentage of a maximum annual amount of wages for each crew member. If the membership of the crew changes during the year, the taxes paid by the owner are higher than during a year in which the crew is stable. The following least-squares regression accounts for 77 percent of the variance for 58 observations:

$$\hat{Y} = 1.073 + 0.057X \quad \text{(Equation 7)}$$

where $\hat{Y}$ = estimated annual payroll taxes, in dollars
X = annual crew wages, in dollars
($t_b = 13.72$, $p<0.001$, $r^2 = 0.77$)

e. Interest on loans.—The amounts paid by various corporations for interest on loans range from a few dollars to more than \$2,000 in a given year. The dispersion of payments by any corporation over the years is also very high. In many profit-and-loss statements, no interest payments are shown, although the balance sheet shows a substantial loan. The amounts in Table 2 therefore may not reflect the real situation. We use the grand average value (\$504) for predicting costs for old vessels; but interest on assumed loans should be used for estimations for new vessels. The rate used here for prediction is 7.5 percent.

f. Moorage.—The Harbor Department computes the moorage fee on the basis of the length and of the type of vessel. Of 22 vessels analyzed, 16 (50 to 79 feet long, 60- to 110-ton capacity) paid \$450 per year, and 6 (80 feet and longer, 110- to 150-ton capacity) paid \$540 per year.

g. State and county taxes.—In 1968, the California State income tax rate for corporations was 7 percent, with a minimum of \$100. We use this rate in the predictions below. Since the companies are small corporations, they pay no Federal corporate income tax. Taxable income is reported in the personal returns of the shareholders.

The modal value for county property taxes was about \$450. Under a new law (effective 1968), commercial fishing vessels registered in Los Angeles County are assessed at 1 percent of their market value. The current tax rate is about \$10 per \$100 assessed valuation, making the effective tax rate about 0.1 percent of market value per year.

In terms of an equation:

$$\hat{Y} = 0.001X_1 + 0.07X_2 \quad \text{(Equation 8)}$$

where $\hat{Y}$ = the estimated county and State taxes, in dollars

X_1 = the market value of the vessel, in dollars

X_2 = the taxable income during previous year, in dollars

$0.07X_2$ may not be less than \$100

h. Depreciation.—Considered here is the depreciation both for existing and new vessels (including their nets).

(1) Existing vessels.—The straight-line method and the declining balance method of computing depreciation are alternatively applied to the various component parts of the vessels (for example, vessel, engine, and skiff) and equipment (for example, power block, electronics, and netting). The age of the vessels (all are more than 20 years old, and about half of the fleet is more than 30 years old), explains why the cost of depreciation is rather low on the average (Table 16). In 1968, the market value of the vessels ranged from \$25,000 to \$60,000 (average value, \$41,530; modal value, \$45,000). (Note: The modal value is used below for predicting insurance costs for existing vessels in sample calculations.) The depreciation claimed in 1967 does not show a significant linear relation with market value, because most of the depreciation claimed is on nets, skiffs, electronics, refrigeration, and other vessel improvements, which retain a high market value beyond the span of their short book lives. The grand average value of depreciation for 1963-67 (Table 16) is used below for predictions.

(2) New vessels.—Depreciation for new vessels and skiffs is estimatd at straight line for 15 years on 85 percent of the unsubsidized portion of new construction costs. Table 17 contains estimated costs of new-vessel construction for 12 steel vessels of various lengths, capacities, and horsepower. The total cost of a new net is depreciated straight line over 5 years. A new seine costs about \$12,000. Most vessel operators own two seines--one for mackerel and one with a smaller mesh for anchovies. In equation form:

$$\hat{Y} = 0.057X_1 + 0.2X_2 \qquad \text{(Equation 9)}$$

where $\hat{Y}$ = estimated depreciation, in dollars

Table 17.—Estimated costs of new vessel construction (steel)

Vessel Number	Vessel data								Remarks	Skiff data			
	Length	Beam	Depth	Fish capacity	Size of motor	Speed: Light	Speed: Loaded	Cost		Length	Beam	Size of motor	Cost
	Feet	*Feet*	*Feet*	*Short tons*	*Horse-power*	*Knots*	*Knots*	*Dollars*		*Feet*	*Feet*	*Horse-power*	*Dollars*
1	54.0	16.5	8.0	61	160	9.5-9.8	8.5	120,000	Combination boat. In 1959 it cost \$80,000 for a basic boat and \$110,000 for a fully equipped one for seining and trawling.	16	8	60	8,000
2	58.0	18.0	9.0	66	240	10.2	--	140,000	Seiner.	16-17	9	--	9,000
3	58.0	--	--	60	--	--	--	160,000	Seiner.	--	--	--	--
4	60.0	20.0	--	60	275	10.5	--	140,000	Combination boat.	--	--	--	--
5	66.0	19.5	9.5	110	260	10.2	8.5-9.0	160,000-180,000	Combination boat. In 1968 it cost \$230,000 as a fully equipped crab boat.	20	10	100	11,000
6	70.0	22.0	--	110	365	11.0	--	285,000	Combination boat.	--	--	--	--
7	70.0	--	--	120	--	--	--	200,000	Seiner.	--	--	--	--
8	73.0	21.9	10.5	154	350	10.0-10.5	9.0-9.5	180,000-200,000	Combination boat.	22	--	100	14,000
9	80.0	24.0	--	135	510	12.0	--	400,000	Combination boat.	--	--	--	--
10	80.0	--	--	175	--	--	--	260,000	Seiner.	--	--	--	--
11	83.0	24.0	11.5	210	350-400	11.0	9.5	220,000-240,000	Combination boat. Spray refrigerator would cost about \$25,000 more.	22	--	100	14,000
12	90.0	25.0	12.0	264	560	11.5-12.0	10.5	280,000-300,000	Combination boat. In 1968 it cost \$350,000 as a crab boat; \$450,000 as a completely equipped combination boat for trawling, seining, crabbing, scalloping, or salmon hauling; and \$400,000 for a crabbing scalloping combination.	24	12	100	15,000

Note 1: The data on cost are for a vessel fully equipped for seining, except for nets and skiffs; the data do not include the cost of refrigeration. The estimates were made in the fall of 1968.
Note 2: These figures are based on data furnished by vessel builders (see Acknowledgements).

X_1 = value of vessel and gear exclusive of nets, in dollars (for 1st year, = 85 percent of new construction cost or full amount of unsubsidized cost for subsidized vessel)

X_2 = value of nets, in dollars

i. Office expenses and other costs.—Table 18 shows the main components of office expenses and other costs.

Table 18.–Office expenses and other costs

Item	Cost
	Dollars
Accounting	450-500
Automobile	400-500
Dues and contributions	200-300

The rest of these costs consists of items such as licenses, legal fees, promotional expenses, telephone, donations, and "miscellaneous." For the predictions below, we use the average figure of $1,873 for the fleet in 1967.

B. MODEL FOR PREDICTION OF EARNINGS

With our analysis of costs, we can construct our model for the prediction of earnings. In so doing, we consider first the prediction of revenue and then the prediction of the aspects of earnings that depend on revenue--namely, profits, return on investment, and crew earnings.

1. Revenue

Predicting revenue turned out to be difficult--in fact, impossible at present. In this section, we describe the problem and how we handled it.

a. Problem of predicting revenue.—Revenue proved difficult to predict because little relation was found in the present study between landings or gross revenue and vessel characteristics such as length, capacity, horsepower of the main engine, or age. Three possible causes of this lack of observed relation are (1) the nature of the fishery, (2) an overriding factor of skill, and (3) insufficient data.

(1) Nature of fishery.—Because the vessels are seldom loaded to capacity (the usual load of mackerel is 10 to 50 tons), differential capacity is of minor importance. The exception to this underloading of the vessel occurs in the anchovy fishery, in which the vessels are loaded to capacity on most trips. Because the fishing grounds are within a few hours run from the harbor at most and, in some places, within a few minutes run, the importance of differential horsepower is minimized. Also, the catches of some species are subject to limits set by processors.

(2) Overriding skill factor.—Setting a purse seine around a school of fish requires great skill. Schooling behavior varies widely from species to species and even from one school to another within a particular species, and empty hauls are common. Differences in the fishing ability of vessel captains may therefore be the major source of variation in landings and revenue.

(3) Insufficient data.—Few data were available for the present study on fishing effort (days at sea, scouting time, and number of net sets) correlated with landings data. The staff of Marine Resources Operations of the California Department of Fish and Game, however, is now collecting effort data for the fleet. When adjustments can eventually be made for differences in fishing effort, we may find that differences in efficiency are correlated with vessel characteristics.

b. Solution to the problem of predicting earnings.—Because of our difficulty in predicting revenue, we use arbitrary levels of revenue to predict the costs and earnings in the following section. Our range of values includes levels of revenue attained by vessels in the fleet in recent years (Figures 6 and 7).

2. Profit, Return on Investment, and Crew Earnings

Profit, return on investment, and crew earnings may be predicted for given levels of gross revenue by the use of the cost relations developed earlier. The following subsection gives

details both for the older vessels of the type now in the fleet and for hypothetical new vessels.

a. Existing vessels.—In this section, we are concerned with sample calculations--that is, with showing our technique to calculate predictions of profit, return on investment, and crew earnings. Table 19 is a guide to illustrate the method used to estimate profit and return on investment. The following example, which is keyed to Table 19 by column numbers, illustrates the details of computation. Sources of the relations or values used in the computations are indicated in parentheses.

Given: Vessel size = 100 tons capacity

Market value = $45,000 (modal value for fleet; actual market value should be substituted by the prospective vessel operator)

Gross revenue = $150,000

Catch = One-half mackerel and one-half anchovies, by value

Nets = One for anchovies and one for mackerel, at $12,000 each

Then:

	Column in Table 19
1. Operating costs (by Equation 1) = $8,052 + 0.0275 × value of mackerel landings + 0.0419 × value of tuna landings + 0.0939 × value of bonito landings + 0.0380 × value of anchovy landings = $8,052 + 0.0275 × $75,000 + 0.0380 × $75,000 = $12,965	1
2. Tons of mackerel = value of mackerel landings ÷ price per ton (from Table 3; the current price should be substituted by the prospective vessel operator) = $75,000 ÷ $75.42 per ton = 994 tons	2
3. Tons of anchovies = the value of the anchovy landings ÷ the price per ton (from Table 3; the current price should be substituted by the prospective vessel operator) = $75,000 ÷ $20 per ton = 3,750 tons	5
4. Total tons of fish = Column 2 + Column 3 + Column 4 + Column 5 = 4,744 tons	6
5. Minimum number of trips, assuming a capacity load each trip = total tons (Column 6) ÷ capacity of vessel = 994 tons + 3,750 tons ÷ 100 tons = 48 trips (= about 1 trip per week)	7
6. Net proceeds = gross revenue — operating costs (Column 1) = $150,000 — $12,965 = $137,035	8
7. Percentage to crew (from Table 4) = 61 percent	9
8. Gross crew share = percentage to crew (Column 9) × net proceeds (Column 8) ÷ 100 = 61 percent × $137,035 ÷ 100 = $83,591	10
9. Individual crew share = gross crew share (Column 10) ÷ size of crew (from Table 4) = $83,591 ÷ 11 or 10 = $7,599 to $8,359 per individual	11
10. Owner's share = net proceeds (Column 8) — gross crew share (Column 10) = $137,035 — $83,591 = $53,444	12
11. Parts and repairs (using Equation 2) = $24 + 0.0787 × owner's share (Column 12) + 0.0552 × owner's share in the preceding year (assumed here to be same as for the year 1969) = $24 + 0.0787 × $53,444 + 0.0552 × $53,444 = $7,180	13
12. Netting and supplies (using Equation 4) = — $240 + $2 per ton × tons of fish landed (Column 6)	

Table 19.—Sample calculations of predicted earnings for existing vessels, at gross revenue = $150,000

Catch composition by value	Vessel capacity	Column 1 Operating cost	Column 2 Mackerel	Column 3 Tuna	Column 4 Bonito	Column 5 Anchovies	Column 6 Total fish	Column 7 Trips
	Tons	*Dollars*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Number*
Approximate composition of 1967 fleet landings (Figure 4), i.e., 50 percent mackerel, 10 percent tuna, 25 percent bonito, and 15 percent anchovies	70	15,270	994	60	441	1,125	2,620	38
	100	15,270	994	60	441	1,125	2,620	27
	120	15,270	994	60	441	1,125	2,620	22
	150	15,270	994	60	441	1,125	2,620	18
50 percent mackerel and 50 percent anchovies	70	12,965	994	0	0	3,750	4,744	68
	100	12,965	994	0	0	3,750	4,744	48
	120	12,965	994	0	0	3,750	4,744	40
	150	12,965	994	0	0	3,750	4,744	32
100 percent anchovies	70	13,752	0	0	0	7,500	7,500	108
	100	13,752	0	0	0	7,500	7,500	75
	120	13,752	0	0	0	7,500	7,500	63
	150	13,752	0	0	0	7,500	7,500	50

Catch composition by value	Vessel capacity	Column 8 Net proceeds	Column 9 Proportionate crew share	Column 10 Gross crew share	Column 11 Individual crew share	Column 12 Owner's share	Column 13 Parts and repairs
		Dollars	*Percent*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Approximate composition of 1967 fleet landings (Figure 4), i.e., 50 percent mackerel, 10 percent tuna, 25 percent bonito, and 15 percent anchovies	70	134,730	62.5	84,206	8,421-9,356	50,524	6,789
	100	134,730	61.0	82,185	7,471-8,219	52,545	7,060
	120	134,730	60.5	81,512	7,410-8,151	53,218	7,150
	150	134,730	58.5	78,817	6,568-7,165	55,913	7,511
50 percent mackerel and 50 percent anchovies	70	137,035	62.5	85,647	8,565-9,516	51,388	6,905
	100	137,035	61.0	83,591	7,599-8,359	53,444	7,180
	120	137,035	60.5	82,906	7,537-8,291	54,129	7,272
	150	137,035	58.5	80,165	6,680-7,288	56,870	7,639
100 percent anchovies	70	136,248	62.5	85,155	8,516-9,462	51,093	6,865
	100	136,248	61.0	83,111	7,556-8,311	53,137	7,139
	120	136,248	60.5	82,430	7,494-7,971	53,818	7,230
	150	136,248	58.5	79,705	6,642-7,246	56,543	7,595

Catch composition by value	Vessel capacity	Column 14 Netting and supplies	Column 15 Insurance	Column 16 Payroll taxes	Column 17 Interest on loans	Column 18 Moorage	Column 19 State and county taxes
		Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Approximate composition of 1967 fleet landings (Figure 4), i.e., 50 percent mackerel, 10 percent tuna, 25 percent bonito, and 15 percent anchovies	70	5,480	6,658	5,873	504	450	1,480
	100	5,480	6,858	5,758	504	450	1,480
	120	5,480	6,858	5,719	504	540	1,480
	150	5,480	7,058	5,566	504	540	1,480
50 percent mackerel and 50 percent anchovies	70	9,248	6,658	5,955	504	450	1,235
	100	9,248	6,858	5,838	504	450	1,235
	120	9,248	6,858	5,799	504	540	1,235
	150	9,248	7,058	5,642	504	540	1,235
100 percent anchovies	70	15,240	6,658	5,927	504	450	780
	100	15,240	6,858	5,810	504	450	780
	120	15,240	6,858	5,772	504	540	780
	150	15,240	7,058	5,616	504	540	780

Catch composition by value	Vessel capacity	Column 20 Depreciation	Column 21 Office expenses	Column 22 Total owner's costs	Column 23 Net profit	Column 24 Equity capital investment	Column 25 Return on investment
		Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Percent*
Approximate composition of 1967 fleet landings (Figure 4), i.e., 50 percent mackerel, 10 percent tuna, 25 percent bonito, and 15 percent anchovies	70	3,604	1,873	32,711	17,813	28,162	63.3
	100	3,604	1,873	33,067	19,478	28,162	69.2
	120	3,604	1,873	33,208	20,010	28,162	71.2
	150	3,604	1,873	33,616	22,297	28,162	79.2
50 percent mackerel and 50 percent anchovies	70	3,604	1,873	36,442	14,946	28,162	53.1
	100	3,604	1,873	36,790	16,654	28,162	59.1
	120	3,604	1,873	36,943	17,186	28,162	61.0
	150	3,604	1,873	37,353	19,517	28,162	69.3
100 percent anchovies	70	3,604	1,873	41,901	9,192	28,162	32.6
	100	3,604	1,873	42,258	10,879	28,162	38.6
	120	3,604	1,873	42,401	11,417	28,162	40.5
	150	3,604	1,873	42,810	13,733	28,162	48.8

Column in Table 19

$= - \$240 + \$2 \times 4{,}744 = \$9{,}248$ 14

13. Insurance (using Equation 5) = $0.0675 \times$ market value of vessel + $0.05 \times$ value of nets + \$200 per crewman $\times$ maximum crew size (from Table 4) = $0.0675 \times \$45{,}000 + 0.0500 \times \$24{,}000$ (assuming two new nets at \$12,000 each) + $\$200 \times 11 = \$6{,}858$ 15

14. Payroll taxes (using Equation 7) = $\$1{,}073 + 0.057 \times$ gross crew share of net proceeds (Column 10) = $\$1{,}073 + \$.057 \times \$83{,}591 = \$5{,}838$ 16

15. Interest on loans (using average value for 1967 from Table 16; the prospective vessel operator should substitute his actual estimate) = \$504 17

16. Moorage (using average paid by vessels under 80 feet long, Moorage section) = \$450 18

17. State and county taxes (using Equation 8) = $0.001 \times$ market value of vessel + $0.07 \times$ previous year's profit (assumed here to be \$17,000), with the limitation that this term may not be less than \$100 (the prospective vessel operator should substitute \$100 as the State tax during his first year of operation) = $0.001 \times \$45{,}000 + 0.07 \times \$17{,}000 = \$1{,}235$ 19

18. Depreciation (using average value for 1963 to 1967 from Table 16; the prospective vessel operator should substitute his actual estimate) = \$3,604 20

19. Office expenses and other costs (using average value for 1967 from Table 16) = \$1,873 21

20. Total owner's costs = parts and repairs (Column 13) + netting and supplies (Column 14) + insurance (Column 15) + payroll taxes (Column 16) + interest on loans (Column 17) + moorage (Column 18) + State and county taxes (Column 19) + depreciation (Column 20) + office expenses and other costs (Column 21) = \$7,180 + \$9,248 + \$6,858 + \$5,838 + \$504 + \$450 + \$1,235 + \$3,604 + \$1,873 = \$36,790 22

21. Net profit = owner's share (Column 12) — total owner's cost (Column 22) = \$53,444 — \$36,790 = \$16,654 23

22. Equity capital investment (from Capital Structure and Return on Investment section; the actual anticipated capital investment should be substituted by the prospective vessel operator) = \$28,162 24

23. Return on investment = net profit (Column 23) ÷ capital investment (Column 24) = \$16,654 ÷ \$28,162 = 59.1 percent 25

b. New vessels. — Before predicting profits and return on investment for new vessels, we must hypothesize a capital structure (Table 20).

Table 21 illustrates the method used to predict earnings for hypothetical new vessels. The vessel types are selected from Table 17. The following example is keyed to Table 21 by column numbers.

Given: Vessel size = 110 tons capacity (vessel-type Number 5 in Table 17)

Vessel cost (including skiff, two nets, and spray, refrigeration) = \$226,000 (Table 17)

Gross revenue = \$150,000

Table 20.–Capital structure for new vessel owners, under various levels of government vessel-construction subsidy

Vessel type (from Table 16)	Capital structure with no subsidy:								
	Fixed capital					Working capital[1]	Total capital	Borrowed capital[2]	Net worth
	Vessel	Skiff	Refrigeration	Nets	Total				
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
1	120,000	8,000	19,000	24,000	171,000	8,550	178,550	113,000	65,550
2	140,000	9,000	19,000	24,000	192,000	9,600	200,600	127,000	73,600
3	160,000	9,000	19,000	24,000	212,000	10,600	221,600	140,000	81,600
4	140,000	10,000	21,000	24,000	195,000	9,750	203,750	129,000	74,750
5	170,000	11,000	21,000	24,000	226,000	11,300	236,300	150,000	86.300
6	285,000	14,000	23,000	24,000	346,000	17,300	362,300	230,000	132,300
7	200,000	14,000	23,000	24,000	261,000	13,050	273,050	173,000	100,050
8	190,000	14,000	23,000	24,000	251,000	12,550	262,550	166,000	96,550
9	400,000	15,000	25,000	24,000	464,000	23,200	486,200	308,000	178,200
10	260,000	14,000	25,000	24,000	323,000	16,150	338,150	214,000	124,150
11	230,000	14,000	25,000	24,000	293,000	14,650	306,650	194,000	112,650
12	290,000	15,000	25,000	24,000	354,000	17,700	370,000	235,000	135,700

Vessel type (from Table 16)	Capital structure with 40-percent subsidy:						
	Fixed capital			Working capital[1]	Total capital	Borrowed capital[2]	Net worth
	Vessel[3]	Nets	Total				
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
1	88,000	24,000	112,000	8,550	120,550	75,000	45,550
2	101,000	24,000	125,000	9,600	134,600	83,000	51,600
3	113,000	24,000	137,000	10,600	147,600	91,000	56,600
4	103,000	24,000	127,000	9,750	136,750	85,000	51,750
5	121,000	24,000	145,000	11,300	156,300	97,000	59,300
6	193,000	24,000	217,000	17,300	234,300	145,000	89,300
7	142,000	24,000	166,000	13,050	179,050	111,000	68,050
8	136,000	24,000	160,000	12,550	172,550	107,000	65,550
9	264,000	24,000	288,000	23,200	311,200	192,000	119,200
10	179,000	24,000	203,000	16,150	219,150	135,000	84,150
11	161,000	24,000	105,000	14,650	199,650	123,000	76,650
12	198,000	24,000	222,000	17,700	239,700	148,000	91,700

Vessel type (from Table 16)	Capital structure with 50-percent subsidy:						
	Fixed capital			Working capital[1]	Total capital	Borrowed capital[2]	Net worth
	Vessel[3]	Nets	Total				
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
1	73,500	24,000	97,500	8,550	106,050	65,000	41,050
2	84,000	24,000	108,000	9,600	117,600	72,000	45,600
3	94,000	24,000	118,000	10,600	128,600	79,000	49,600
4	86,000	24,000	110,000	9,750	119,750	73,000	46,750
5	101,000	24,000	125,000	11,300	136,300	83,000	53,300
6	161,000	24,000	105,000	17,300	202,300	123,000	79,300
7	118,000	24,000	142,000	13,050	155,050	95,000	60,050
8	114,000	24,000	138,000	12,550	150,550	92,000	58,550
9	220,000	24,000	244,000	23,200	267,200	163,000	104,200
10	150,000	24,000	174,000	16,150	190,150	116,000	74,150
11	135,000	24,000	159,000	14,650	173,650	106,000	67,650
12	165,000	24,000	189,000	17,700	206,700	126,000	80,700

[1] Working capital consists of 5 percent of full value of fixed capital.
[2] Borrowed capital consists of 66.6 percent of fixed capital.
[3] For subsidized vessels, the fixed capital in the vessel includes the skiff and the refrigeration.

Catch = One-half mackerel and one-half anchovies, by value.

Then:

Column in Table 21

1. Operating costs (using Equation 1) = \$8,052 + 0.0275 × value of mackerel landings + 0.0419 × value of tuna landings + 0.0939 × value of bonito landings + 0.0380 × value of anchovy landings = \$8,052 + 0.0275 × \$75,000 + 0.0380 × \$75,000 = \$12,964 1
2. Tons of mackerel = value of mackerel landings ÷ price per ton for 1967 (from Table 3; the current price should be substituted by the prospective vessel operator) = \$75,000 ÷ \$72.50 per ton = 1,034 tons 2
3. Tons of anchovies = the value of anchovy landings ÷ the price per ton of anchovies (from Table 3; the current price should be substituted by the prospective vessel operator) = \$75,000 ÷ \$20 per ton = 3,750 tons 5
4. Total tons of fish = Column 2 + Column 3 = Column 4 + Column 5 = 4,784 tons 6
5. Minimum number of trips, assuming a capacity load each trip = total tons (Column 6) ÷ capacity of the vessel = 4,784 ÷ 110 tons per trip = 44 trips 7
6. Net proceeds = gross revenue — operating costs (Column 1) = \$150,000 — \$12,964 = \$137,036 .. 8
7. Percentage to crew (from Table 4) = 60.5 percent 9
8. Gross crew share = percentage to crew (Column 9) × net proceeds (Column 8) = 60.5 percent × \$137,036 = \$82,907 10
9. Individual crew share = the gross crew share (Column 10) ÷ the size of the crew (from Table 4) = \$83,768 ÷ 11 and 10 = \$7,537 to \$8,291 11
10. Owner's share = the net proceeds (Column 8) — the gross crew share (Column 10) = \$137,036 — \$82,907 = \$54,129 12
11. Parts and repairs (using Equation 3) = — \$17,619 + \$341.15 per foot × length of vessel = — \$17,619 + \$341.15 per foot × 66 feet (from Table 21) = \$4,897 13
12. Netting and supplies (using Equation 4) = — \$240 + \$2 per ton × tons of fish landed (Column 6) = — \$240 + \$2 × 4,784 = \$9,328 . 14
13. Insurance (using Equation 6) = 0.0375 × value of vessel (including skiff and refrigeration) + 0.05 × value of nets + \$200 per crew member × maximum crew size (from Table 4) = 0.0375 × \$202,000 + 0.05 × \$24,000 + \$200 × 11 = \$10,975 15
14. Payroll taxes (using Equation 7) = \$1,073 + 0.057 × gross crew share of net proceeds (Column 9) = \$1,073 + 0.057 × \$82,907 = \$5,799 16
15. Interest on loans (7.5 percent of borrowed capital for vessel number 5 in Table 20) = \$11,250 17
16. Moorage (using average paid by vessels under 80 feet long, Moorage section) = \$450 18
17. State and county taxes (using Equation 8) = 0.001 × value of fixed assets (Table 20) + 0.07 × previous year's profit (assumed here to be \$0) = 0.001 × \$226,000 + 0.07 × \$0 = \$226.00 19
18. Depreciation (using Equation 9) = 0.057 × value of vessel and gear

Table 21.—Sample calculations of predicted earnings for new vessels,

Catch composition by value	Vessel capacity	Column 1 Operating cost	Column 2 Mackerel	Column 3 Tuna	Column 4 Bonito	Column 5 Anchovies	Column 6 Total fish	Column 7 Trips
	Tons	*Dollars*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Number*
Approximate composition of 1967 fleet landings (Figure 4), i.e., 50 percent mackerel, 10 percent tuna, 25 percent bonito, and 15 percent anchovies	66	15,119	1,034	60	452	1,125	2,671	41
	110	15,119	1,034	60	452	1,125	2,671	25
	154	15,119	1,034	60	452	1,125	2,671	18
	210	15,119	1,034	60	452	1,125	2,671	13
	264	15,119	1,034	60	452	1,125	2,671	11
50 percent mackerel and 50 percent anchovies	66	12,964	1,034	0	0	3,750	4,784	73
	110	12,964	1,034	0	0	3,750	4,784	44
	154	12,964	1,034	0	0	3,750	4,784	31
	210	12,964	1,034	0	0	3,750	4,784	23
	264	12,964	1,034	0	0	3,750	4,784	19
100 percent anchovies	66	13,752	0	0	0	7,500	7,500	114
	110	13,752	0	0	0	7,500	7,500	69
	154	13,752	0	0	0	7,500	7,500	49
	210	13,752	0	0	0	7,500	7,500	36
	264	13,752	0	0	0	7,500	7,500	29

Catch composition by value	Vessel capacity	Column 14 Netting and supplies	Column 15 Insurance	Column 16 Payroll taxes	Column 17 Interest on loans	Column 18 Moorage	Column 19 State and county taxes
	Tons	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Approximate composition of 1967 fleet landings (Figure 4), i.e., 50 percent mackerel, 10 percent tuna, 25 percent bonito, and 15 percent anchovies	66	5,102	9,500	5,878	9,525	450	292
	110	5,102	10,975	5,724	11,250	450	226
	154	5,102	12,112	5,494	12,450	450	251
	210	5,102	13,688	5,494	14,550	540	293
	264	5,102	15,975	5,494	17,625	540	354
50 percent mackerel and 50 percent anchovies	66	9,328	9,500	5,955	9,525	450	192
	110	9,328	10,975	5,799	11,250	450	226
	154	9,328	12,112	5,564	12,450	450	251
	210	9,328	13,688	5,564	14,500	540	293
	264	9,328	15,975	5,564	17,625	540	354
100 percent anchovies	66	14,760	9,500	5,927	9,525	450	192
	110	14,760	10,975	5,772	11,250	450	226
	154	14,760	12,112	5,539	12,450	450	251
	210	14,760	13,688	5,539	14,550	540	293
	264	14,760	15,975	5,539	17,625	540	354

Column in Table 21

(unsubsidized portion) exclusive of nets + 0.2 × value of nets = 0.057 × \$202,000 + 0.2 × \$24,000 = \$16,314 20

19. Office expenses and other costs (using the average value for 1967 from Table 16) = \$1,873 21

20. Total owner's costs = parts and repairs (Column 13) + netting and supplies (Column 14) + insurance (Column 15) + payroll taxes (Column 16) + interest on loans (Column 17) + moorage (Column 18) + State and county taxes (Column 19) + depreciation (Column 20) + office expenses and other costs (Column 21) = \$4,897 + \$9,328 + \$10,975 + \$5,799 + \$11,250 + \$450 + \$226 + \$16,314 + \$1,873 = \$61,112 22

21. Net profit = owner's share (Column 12) — total owner's costs (Column 22) = \$54,129 — \$61,112 = —\$6,983 23

22. Capital investment (net worth in Table 20) = \$86,000 24

23. Return on investment = net profit (Column 23) ÷ capital investment (Column 24) = —\$6,983 ÷ \$86,300 = — 8.1 percent 25

at gross revenue = $150,000 and with no construction subsidy

Catch composition by value	Vessel capacity	Column 8	Column 9	Column 10	Column 11	Column 12	Column 13
		Net proceeds	Proportionate crew share	Gross crew share	Individual crew share	Owner's share	Parts and repairs
	Tons	*Dollars*	*Percent*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
Approximate composition of 1967 fleet landings (Figure 4), i.e., 50 percent mackerel, 10 percent tuna, 25 percent bonito, and 15 percent anchovies	66	134,881	62.5	84,301	8,430-9,367	50,580	2,168
	110	134,881	60.5	81,603	7,418-8,160	53,278	4,897
	154	134,881	57.5	77,557	6,463-7,051	57,324	7,285
	210	134,881	57.5	77,557	6,463-7,051	57,324	10,696
	264	134,881	57.5	77,557	6,463-7,051	57,324	13,084
50 percent mackerel and 50 percent anchovies	66	137,036	62.5	85,647	8,565-9,516	51,389	2,168
	110	137,036	60.5	82,907	7,537-8,291	54,129	4,897
	154	137,036	57.5	78,796	6,566-7,163	58,240	7,285
	210	137,036	57.5	78,796	6,566-7,163	58,240	10,696
	264	137,036	57.5	78,796	6,566-7,163	58,240	13,084
100 percent anchovies	66	136,248	62.5	85,155	8,516-9,462	51,093	2,168
	110	136,248	60.5	82,430	7,494-8,243	53,818	4,897
	154	136,248	57.5	78,343	6,529-7,122	57,905	7,285
	210	136,248	57.5	78,343	6,529-7,122	57,905	10,696
	264	136,248	57.5	78,343	6,529-7,122	57,905	13,084

Catch composition by value	Vessel capacity	Column 20	Column 21	Column 22	Column 23	Column 24	Column 25
		Depreciation	Office expenses	Total owner's costs	Net profit	Equity capital investment	Return on investment
	Tons	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Percent*
Approximate composition of 1967 fleet landings (Figure 4), i.e., 50 percent mackerel, 10 percent tuna, 25 percent bonito, and 15 percent anchovies	66	14,376	1,873	49,164	1,416	73,600	1.9
	110	16,314	1,873	56,811	—3,533	86,300	—4.1
	154	17,739	1,873	62,756	—5,432	96,550	—5.6
	210	20,133	1,873	72,369	—15,045	112,650	—13.4
	264	23,610	1,873	83,657	—26,333	135,700	—19.4
50 percent mackerel and 50 percent anchovies	66	14,376	1,873	53,367	—1,978	73,600	—2.7
	110	16,314	1,873	61,112	—6,983	86,300	—8.1
	154	17,739	1,873	67,052	—8,812	96,550	—9.1
	210	20,133	1,873	76,665	—18,425	112,650	—16.4
	264	23,610	1,873	87,953	—29,713	135,700	—21.9
100 percent anchovies	66	14,376	1,873	58,771	—7,678	73,600	—10.4
	110	16,314	1,873	66,517	—12,699	86,300	—14.7
	154	17,739	1,873	72,459	—14,554	96,550	—15.1
	210	20,133	1,873	82,072	—24,167	112,650	—21.5
	264	23,610	1,873	93,360	—35,455	135,700	—26.1

III. ECONOMIC FEASIBILITY OF FLEET EXPANSION AND NEW-VESSEL CONSTRUCTION

We can use our model to calculate the feasibility of expanding the fleet and of constructing new vessels. We consider first the expansion of the fleet with existing vessels and then consider the addition of new construction.

A. FLEET EXPANSION WITH EXISTING VESSELS

In this section, we present a table summarizing predicted earnings for old vessels, and then analyze the table and reach a conclusion as to the economic feasibility of fleet expansion with existing surplus vessels from other fisheries.

1. Summary Table

Table 22 summarizes predicted earnings for old vessels under varying conditions of gross revenue.

2. Analysis of Summary Table and Conclusions

Within the limits of the summary table (Table 22), the crew share is most affected by the size of the vessel (maximum effect at $200,000 gross revenue = $3,015) and is little affected by the species composition of the catch (maximum effect at $200,000 gross revenue = $179). The highest crew share at any level of revenue is achieved on a 70-ton vessel with a half-mackerel, half-anchovy catch, by value.

Table 22.–Summary table of predicted annual earnings for existing vessels

Gross revenue	Vessel size (capacity)	Summary of earnings data when landings are composed, by value, of:							
		Same species in same proportions as in landings for 1967 (Figure 4)				100 percent mackerel			
		Landings	1 crew share	Profit or loss	Return on investment	Landings	1 crew share	Profit or loss	Return on investment
Dollars	*Tons*	*Tons*	*Dollars*	*Dollars*	*Percent*	*Tons*	*Dollars*		*Percent*
50,000	70	871	2,745	–4,882	–17.3	663	2,258	–3,187	–11.3
	100	871	2,411	–4,534	–16.1	663	2,204	–2,970	–10.5
	120	871	2,392	–4,442	–15.8	663	2,186	–2,878	–10.2
	150	871	2,102	–3,913	–13.9	663	2,114	–2,343	– 8.3
100,000	70	1,742	6,068	5,828	20.7	1,326	6,080	7,328	26.0
	100	1,742	5,330	6,829	24.2	1,326	5,340	8,341	29.6
	120	1,742	5,287	7,142	25.4	1,326	5,297	8,745	31.1
	150	1,742	4,647	8,696	30.9	1,326	4,656	10,071	35.8
150,000	70	2,620	9,350	17,813	63.3	1,988	9,396	19,188	68.1
	100	2,620	8,219	19,478	69.2	1,988	8,254	20,861	74.1
	120	2,620	8,151	20,010	71.2	1,988	8,186	22,004	78.1
	150	2,620	7,165	22,297	79.2	1,988	7,196	23,694	84.1
200,000	70	3,484	12,696	29,035	103.1	2,652	12,719	30,544	108.5
	100	3,484	11,152	31,373	111.4	2,652	11,132	32,881	116.8
	120	3,484	11,061	32,121	114.1	2,652	11,081	33,629	119.4
	150	3,484	9,723	35,353	125.5	2,652	9,740	36,817	130.7

Gross revenue	Vessel size (capacity)	Summary of earnings data when landings are composed, by value, of:							
		50 percent mackerel, 50 percent anchovies				100 percent anchovies			
		Landings	1 crew share	Profit or loss	Return on investment	Landings	1 crew share	Profit or loss	Return on investment
Dollars	*Tons*	*Tons*	*Dollars*	*Dollars*	*Percent*	*Tons*	*Dollars*	*Dollars*	*Percent*
50,000	70	1,561	2,799	–6,037	–21.4	2,500	2,781	–7,934	–28.2
	100	1,561	2,459	–5,678	–20.2	2,500	2,443	–7,635	–27.1
	120	1,561	2,439	–5,583	–19.8	2,500	2,423	–7,541	–26.8
	150	1,561	2,144	–5,038	–17.9	2,500	2,130	–7,001	–24.9
100,000	70	3,122	6,157	4,576	16.2	5,000	6,121	919	3.3
	100	3,122	5,408	5,604	19.9	5,000	5,377	1,911	6.8
	120	3,122	5,365	5,917	21.0	5,000	5,333	2,200	7.8
	150	3,122	4,715	7,361	26.1	5,000	4,688	3,528	12.5
150,000	70	4,744	9,516	14,946	53.1	7,500	9,462	9,192	32.6
	100	4,744	8,359	16,644	59.1	7,500	8,311	10,879	38.6
	120	4,744	8,291	17,186	61.0	7,500	7,971	11,417	40.5
	150	4,744	7,288	19,517	69.3	7,500	7,246	13,733	48.8
200,000	70	6,244	12,875	24,728	87.8	10,000	12,802	17,324	61.5
	100	6,244	11,309	27,037	96.0	10,000	11,245	19,683	69.9
	120	6,244	11,217	27,893	99.0	10,000	11,153	20,445	72.6
	150	6,244	9,860	31,026	110.1	10,000	9,804	23,431	83.2

For the vessel operator, profit and return on investment are most affected by the composition of the catch (maximum effect at $200,000 gross revenue = $13,386, between 100 percent mackerel and 100 percent anchovy catch). A dichotomy of interest exists between the crewman and the vessel owner in that the effect of vessel size on profit and return on investment is opposite to that on crew share (maximum effect at $200,000 = $2,730). The highest profit and return on investment at any level of revenue is on a 150-ton vessel with an all-mackerel catch. The break-even point for a 150-ton vessel ranges from a gross revenue of about $65,000 for an all-mackerel catch to about $90,000 for an all-anchovy catch. We conclude that, given favorable market conditions, it is economically feasible to expand the wetfish fleet with surplus vessels from other fisheries at present levels of landings and prices.

B. FLEET EXPANSION AND BOAT REPLACEMENT WITH NEW BOATS

Using the same approach as with old vessels, we first present our tables summarizing the data and then present our analyses of the tables and our conclusions regarding the economic feasibility of new-vessel construction.

1. Summary Tables

Tables 23A, 23B, 23C, and 24 summarize predicted earnings under varying conditions of gross revenue, size of vessel, composition of catch, and construction subsidy. For these computations we assumed an arbitrary 7.5 percent interest rate on borrowed capital, which in turn was set also arbitrarily at 66.6 percent of fixed capital (Table 20). In this way the return to total capital has been split into two parts: return to borrowed capital (in the form of interest paid, as part of fixed costs) and return to equity capital (in the form of profits, as shown in Tables 23A, B, and C). The rate of return to equity capital depends then on the assumed interest rate on borrowed capital. Since this interest rate may vary greatly, it is appropriate to calculate the rate of return to total capital as an alternative way of expressing the return on investment. For this purpose the interest costs were added to profits, and the new profit values were then related to total capital from Table 20. These rates of return to total capital are summarized in Table 24.

2. Analysis of Summary Tables and Conclusions

As was found for vessels of the type now in use (Table 22), the crew share is most affected by the size of the vessel. Profit is also greatly affected by the size of the vessel (maximum effect at $250,000 gross revenue with a 50-percent subsidy = $14,310). Profit is most affected by the species composition of the catch (maximum effect at $250,000 gross revenue with 50-percent subsidy = $17,982). The highest profit at the $250,000 level of gross revenue is attained on the 154-ton vessel with an all-mackerel catch. At lower levels of gross revenue, the profit is greatest with the smallest vessel (66 tons capacity). The highest rate of return on investment is also with the smallest vessel, at all levels of gross revenue. The break-even point for a 66-ton vessel with no subsidy and with an all-mackerel catch is about $140,000, which is near the upper end of the range of gross revenue for the existing fleet in 1967 (Figure 8). A new 66-ton vessel, landing a catch with the same species composition as that in the 1967 landings of the fleet, would have to have a gross revenue of over $250,000 to achieve the levels of profit obtained by the top boats in the existing fleet in 1967 ($30,000, about a 30-percent return on investment for a new 66-ton vessel). This revenue is well above the maximum achieved by any boat in the existing fleet in any year. With a 50-percent construction subsidy, the amount of revenue needed drops to about $225,000, which is still a very high figure relative to the revenue obtained by the fleet in the past. For an all-anchovy catch, the break-even point for a 66-ton vessel with a 50-percent subsidy is about $145,000 gross revenue (7,250 tons of anchovies, or 110 capacity loads), and the profit at $250,000 gross revenue (12,500 tons of anchovies, or 190 capacity loads--a probably unachievable rate of catch) is only $22,321, an amount less than the profit for the top vessels in the existing fleet in 1967.

The predicted unprofitability of new vessels is caused by the high investment base. The lowest cost of a new vessel (from Table 20) is $147,000 (vessel with skiff and refrigeration), whereas the average market value of a vessel in the existing fleet is $45,000. This difference in value causes an extremely high increase in the following categories of fixed costs: insurance, depreciation, and interest on capital. The increase in fixed costs is partly offset by lower repair costs on new vessels. On two comparable vessels, for example, shown in the sample calculations of foregoing sections, the total owner's costs at a level of $150,000 gross revenue have risen from $36,800 on an old vessel to $61,112 on a new one. This means a 66-percent increase in owner's cost effected by higher investment costs, while the owner's share in net proceeds from fishing remains on the same level (about $54,000).

We must conclude that, at present catch rates and fish prices, the construction of new wetfish seiners, even with construction subsidies, for either vessel replacement or fleet expansion is not economically feasible. This situation may change in the future if the efficiency of wetfish seining can be improved through technological research or if new markets can be developed that will yield higher prices for wetfish.

Table 23A.—Summary table of predicted annual earnings for new vessels, with no construction subsidy

Gross revenue	Vessel size (capacity)	Summary of earnings data when landings are composed, by value, of:															
		Same species in same proportions as in landings for 1967 (Figure 4)				100 percent mackerel				50 percent mackerel, 50 percent anchovies				100 percent anchovies			
		Landings	1 crew share	Profit or loss	Return on investment	Landings	1 crew share	Profit or loss	Return on investment	Landings	1 crew share	Profit or loss	Return on investment	Landings	1 crew share	Profit or loss	Return on investment
Dollars	*Tons*	*Tons*	*Dollars*	*Dollars*	*Percent*	*Tons*	*Dollars*	*Dollars*	*Percent*	*Tons*	*Dollars*	*Dollars*	*Percent*	*Tons*	*Dollars*	*Dollars*	*Percent*
	66	1,781	6,058	—12,873	—17.5	1,379	6,194	—11,404	—15.5	3,190	6,158	—15,204	—20.7	5,000	6,121	—19,001	—25.8
	110	1,781	5,278	—18,930	—21.9	1,379	5,396	—17,419	—20.2	3,190	5,365	—21,230	—24.6	5,000	5,333	—25,040	—29.0
100,000	154	1,781	4,560	—22,339	—23.1	1,379	4,663	—20,765	—21.5	3,190	4,635	—24,493	—25.5	5,000	4,608	—28,419	—29.4
	210	1,781	4,560	—31,952	—28.4	1,379	4,663	—30,378	—27.0	3,190	4,635	—34,206	—30.4	5,000	4,608	—38,032	—33.8
	264	1,781	4,560	—43,240	—31.9	1,379	4,663	—41,666	—30.7	3,190	4,635	—45,494	—33.5	5,000	4,608	—49,320	—36.3
	66	2,671	9,367	1,416	1.9	2,069	9,571	3,476	4.7	4,784	9,516	—1,978	—2.7	7,500	9,462	—7,678	—10.4
	110	2,671	8,160	—3,533	—4.1	2,069	8,338	—1,269	—1.5	4,784	8,291	—6,983	—8.1	7,500	8,243	—12,699	—14.7
150,000	154	2,671	7,051	—5,432	—5.6	2,069	7,204	—3,037	—3.1	4,784	7,163	—8,812	—9.1	7,500	7,122	—14,554	—15.1
	210	2,671	7,051	—15,045	—13.4	2,069	7,204	—12,650	—11.2	4,784	7,163	—18,425	—16.4	7,500	7,122	—24,167	—21.5
	264	2,671	7,051	—26,333	—19.4	2,069	7,204	—23,938	—17.6	4,784	7,163	—29,713	—21.9	7,500	7,122	—35,455	—26.1
	66	3,561	12,676	14,864	20.2	2,759	12,948	17,609	23.9	6,378	12,874	10,512	14.3	10,000	12,803	3,407	4.6
	110	3,561	11,042	11,088	12.8	2,759	11,280	13,908	16.1	6,378	11,217	5,854	6.8	10,000	11,153	—358	—.4
200,000	154	3,561	9,542	10,724	11.1	2,759	9,745	13,730	14.2	6,378	9,691	6,513	6.7	10,000	9,636	—242	—.3
	210	3,561	9,542	1,740	1.5	2,759	9,745	4,746	4.2	6,378	9,691	—2,644	—2.3	10,000	9,636	—9,855	—8.7
	264	3,561	9,542	—9,426	—6.9	2,759	9,745	—6,210	—4.6	6,378	9,691	—13,932	—10.3	10,000	9,636	—21,143	—15.6
	66	4,452	15,984	28,310	38.5	3,449	16,325	31,743	43.1	7,974	16,233	22,867	31.1	12,500	16,142	13,991	19.0
	110	4,452	13,925	25,475	29.5	3,449	14,222	29,001	33.6	7,974	14,142	20,101	23.3	12,500	14,063	11,200	13.0
250,000	154	4,452	12,031	26,524	27.5	3,449	12,286	30,298	31.4	7,974	12,219	21,258	22.0	12,500	12,151	12,316	12.8
	210	4,452	12,031	17,540	15.6	3,449	12,286	21,314	18.9	7,974	12,219	12,274	10.9	12,500	12,151	3,332	3.0
	264	4,452	12,031	6,991	5.2	3,449	12,286	10,765	7.9	7,974	12,219	1,725	1.3	12,500	12,151	—7,723	—5.7

Table 23B.—Summary table of predicted annual earnings for new vessels, with 40-percent construction subsidy

Gross revenue	Vessel size (capacity)	Summary of earnings data when landings are composed, by value, of:															
		Same species in same proportions as in landings for 1967 (Figure 4)				100 percent mackerel				50 percent mackerel, 50 percent anchovies				100 percent anchovies			
		Landings	1 crew share	Profit or loss	Return on investment	Landings	1 crew share	Profit or loss	Return on investment	Landings	1 crew share	Profit or loss	Return on investment	Landings	1 crew share	Profit or loss	Return on investment
Dollars	*Tons*	*Tons*	*Dollars*	*Dollars*	*Percent*	*Tons*	*Dollars*	*Dollars*	*Percent*	*Tons*	*Dollars*	*Dollars*	*Percent*	*Tons*	*Dollars*	*Dollars*	*Percent*
	66	1,781	6,058	—5,754	—11.2	1,379	6,194	—4,285	—8.3	3,190	6,158	—8,085	—15.7	5,000	6,121	—11,882	—23.0
	110	1,781	5,278	—10,338	—17.4	1,379	5,396	—8,827	—14.9	3,190	5,365	—12,638	—21.3	5,000	5,333	—16,448	—27.7
100,000	154	1,781	4,560	—12,727	—19.4	1,379	4,663	—11,153	—17.0	3,190	4,635	—14,981	—22.9	5,000	4,608	—18,807	—28.7
	210	1,781	4,560	—20,471	—26.7	1,379	4,663	—18,897	—24.7	3,190	4,635	—27,725	—29.6	5,000	4,608	—26,551	—34.6
	264	1,781	4,560	—29,191	—31.8	1,379	4,663	—27,617	—30.1	3,190	4,635	—31,445	—34.3	5,000	4,608	—35,271	—38.5
	66	2,671	9,367	8,070	15.6	2,069	9,571	9,722	18.8	4,784	9,516	4,805	9.3	7,500	9,462	—559	—1.1
	110	2,671	8,160	4,728	8.0	2,069	8,338	6,633	11.2	4,784	8,296	1,504	2.5	7,500	8,243	—4,107	—6.9
150,000	154	2,671	7,051	3,907	6.0	2,069	7,204	6,161	9.4	4,784	7,163	700	1.1	7,500	7,122	—4,942	—7.5
	210	2,671	7,051	—3,564	—4.6	2,069	7,204	—1,169	—1.5	4,784	7,163	—6,944	—9.1	7,500	7,122	—12,686	—16.6
	264	2,671	7,051	—12,638	—13.8	2,069	7,204	—9,889	—10.8	4,784	7,163	—15,664	—17.1	7,500	7,122	—21,406	—23.3

Table 23B.–Continued

Gross revenue	Vessel size (capacity)	Summary of earnings data when landings are composed, by value, of: Same species in same proportions as in landings for 1967 (Figure 4)				100 percent mackerel				50 percent mackerel, 50 percent anchovies				100 percent anchovies			
		Landings	1 crew share	Profit or loss	Return on investment	Landings	1 crew share	Profit or loss	Return on investment	Landings	1 crew share	Profit or loss	Return on investment	Landings	1 crew share	Profit or loss	Return on investment
Dollars	*Tons*	*Tons*	*Dollars*	*Dollars*	*Percent*	*Tons*	*Dollars*	*Dollars*	*Percent*	*Tons*	*Dollars*	*Dollars*	*Percent*	*Tons*	*Dollars*	*Dollars*	*Percent*
	66	3,561	12,676	21,518	41.7	2,759	12,948	23,449	45.4	6,378	12,874	17,165	33.3	10,000	12,803	10,059	19.5
	110	3,561	11,042	19,118	32.2	2,759	11,280	21,515	36.3	6,378	11,217	14,818	25.0	10,000	11,153	7,695	13.0
200,000	154	3,561	9,542	19,708	30.7	2,759	9,745	22,713	34.6	6,378	9,691	15,496	23.6	10,000	9,636	8,339	12.7
	210	3,561	9,542	12,471	16.3	2,759	9,745	15,475	20.2	6,378	9,691	8,258	10.8	10,000	9,636	1,079	1.4
	264	3,561	9,542	4,322	4.7	2,759	9,745	7,326	8.0	6,378	9,691	17	0	10,000	9,636	–7,541	–8.2
	66	4,452	15,984	34,964	67.8	3,449	16,325	37,176	72.0	7,974	16,233	29,520	57.2	12,500	16,142	20,644	40.0
	110	4,452	13,925	33,505	56.5	3,449	14,222	36,397	61.4	7,974	14,142	28,131	47.4	12,500	14,063	19,259	32.5
250,000	154	4,452	12,031	35,508	54.2	3,449	12,286	39,281	59.9	7,974	12,219	32,358	49.4	12,500	12,151	21,299	32.5
	210	4,452	12,031	28,270	36.9	3,449	12,286	32,043	41.8	7,974	12,219	23,004	30.0	12,500	12,151	14,062	18.3
	264	4,452	12,031	20,121	21.9	3,449	12,286	23,894	26.0	7,974	12,219	14,901	16.2	12,500	12,151	5,912	6.4

Table 23C.–Summary table of predicted annual earnings for new vessels, with 50-percent construction subsidy

Gross revenue	Vessel size (capacity)	Summary of earnings data when landings are composed, by value, of: Same species in same proportions as in landings for 1967 (Figure 4)				100 percent mackerel				50 percent mackerel, 50 percent anchovies				100 percent anchovies			
		Landings	1 crew share	Profit or loss	Return on investment	Landings	1 crew share	Profit or loss	Return on investment	Landings	1 crew share	Profit or loss	Return on investment	Landings	1 crew share	Profit or loss	Return on investment
Dollars	*Tons*	*Tons*	*Dollars*	*Dollars*	*Percent*	*Tons*	*Dollars*	*Dollars*	*Percent*	*Tons*	*Dollars*	*Dollars*	*Percent*	*Tons*	*Dollars*	*Dollars*	*Percent*
	66	1,781	6,058	–3,960	–8.7	1,379	6,194	–2,491	–5.5	3,190	6,158	–6,291	–13.8	5,000	6,121	–10,088	–22.1
	110	1,781	5,278	–8,148	–15.3	1,379	5,396	–6,637	–12.4	3,190	5,365	–10,448	–19.6	5,000	5,333	–14,258	–26.8
100,000	154	1,781	4,560	–10,348	–17.7	1,379	4,663	–8,774	–15.0	3,190	4,635	–12,602	–21.5	5,000	4,608	–16,428	–28.1
	210	1,781	4,560	–17,714	–26.2	1,379	4,663	–16,140	–23.7	3,190	4,635	–19,968	–29.5	5,000	4,608	–23,794	–35.2
	264	1,781	4,560	–25,660	–31.8	1,379	4,663	–24,086	–29.8	3,190	4,635	–27,914	–34.6	5,000	4,608	–31,740	–39.3
	66	2,671	9,367	9,747	21.4	2,069	9,571	11,806	25.9	4,784	9,516	6,481	14.2	7,500	9,462	1,135	2.5
	110	2,671	8,160	6,781	12.7	2,069	8,338	8,891	16.7	4,784	8,296	3,551	6.7	7,500	8,243	–1,917	–3.6
150,000	154	2,671	7,051	6,130	10.5	2,069	7,204	8,368	14.3	4,784	7,163	2,971	5.1	7,500	7,122	–2,563	–4.4
	210	2,671	7,051	–807	–1.2	2,069	7,204	1,484	2.2	4,784	7,163	–4,187	–6.2	7,500	7,122	–9,929	–14.7
	264	2,671	7,051	–8,753	–10.8	2,069	7,204	–6,358	–7.9	4,784	7,163	–12,133	–15.0	7,500	7,122	–17,874	–22.1
	66	3,561	12,676	23,194	50.8	2,759	12,948	25,905	56.8	6,378	12,874	18,842	41.3	10,000	12,803	11,736	25.7
	110	3,561	11,042	21,164	39.7	2,759	11,280	23,984	45.0	6,378	11,217	16,865	31.6	10,000	11,153	9,742	18.3
200,000	154	3,561	9,542	21,931	37.4	2,759	9,745	24,936	42.6	6,378	9,691	17,719	30.3	10,000	9,636	10,562	18.0
	210	3,561	9,542	15,047	22.2	2,759	9,745	18,052	26.7	6,378	9,691	10,835	16.0	10,000	9,636	3,678	5.4
	264	3,561	9,542	7,621	9.4	2,759	9,745	10,626	13.2	6,378	9,691	3,409	4.2	10,000	9,636	–4,008	–5.0
	66	4,452	15,984	36,640	80.4	3,449	16,325	40,005	87.7	7,974	16,233	31,196	68.4	12,500	16,142	22,321	48.9
	110	4,452	13,925	35,551	66.7	3,449	14,222	39,077	73.3	7,974	14,142	30,178	56.6	12,500	14,063	21,276	39.9
250,000	154	4,452	12,031	37,731	64.4	3,449	12,286	41,504	70.9	7,974	12,219	32,465	55.4	12,500	12,151	23,522	40.2
	210	4,452	12,031	30,847	45.6	3,449	12,286	34,620	51.2	7,974	12,219	25,580	37.8	12,500	12,151	16,638	24.6
	264	4,452	12,031	23,421	29.0	3,449	12,286	27,194	33.7	7,974	12,219	18,194	22.5	12,500	12,151	9,212	11.4

Table 24.—Summary table of predicted returns to capital for new vessels

Gross revenue	Vessel size (capacity)	No construction subsidy				40-percent construction subsidy				50-percent construction subsidy			
		Composition of landings by value:				Composition of landings by value:				Composition of landings by value:			
		As in 1967 (Fig. 4)	100 percent mackerel	50 percent mackerel 50 percent anchovies	100 percent anchovies	As in 1967 (Fig. 4)	100 percent mackerel	50 percent mackerel 50 percent anchovies	100 percent anchovies	As in 1967 (Fig. 4)	100 percent mackerel	50 percent mackerel 50 percent anchovies	100 percent anchovies
Dollars	*Tons*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
	66	−1.7	−0.9	−2.8	−4.7	0.3	1.4	−1.4	−4.2	1.2	2.4	−0.7	−4.0
	110	−3.2	−2.6	−4.2	−5.8	−2.0	−1.0	−3.4	−5.9	−1.4	−0.3	−3.1	−5.9
100,000	154	−3.8	−3.2	−4.6	−6.1	−2.7	−1.8	−4.0	−6.2	−2.3	−1.2	−3.8	−6.3
	210	−5.7	−5.2	−6.4	−7.6	−5.6	−4.8	−6.8	−8.7	−5.6	−4.7	−6.9	−9.1
	264	−6.9	−6.5	−7.5	−8.6	−7.5	−6.9	−8.5	−10.1	−7.8	−7.1	−8.9	−10.8
	66	5.5	6.4	3.7	0.9	10.6	11.8	8.1	4.2	12.8	14.6	10.1	5.5
	110	3.3	4.2	1.8	−0.6	7.6	8.9	5.6	2.0	9.5	11.0	7.1	3.1
150,000	154	2.7	3.6	1.3	−0.8	6.9	8.2	5.0	1.7	8.6	10.1	6.5	2.8
	210	−0.2	0.6	−1.3	−3.1	2.8	4.0	1.1	−1.7	4.1	5.4	2.1	−1.1
	264	−2.3	−1.7	−3.3	−4.8	−0.6	0.5	−1.9	−4.3	0.3	1.5	−1.3	−4.1
	66	12.1	13.5	10.0	6.4	20.6	22.0	17.3	12.0	24.3	26.6	20.6	14.5
	110	9.4	10.6	7.2	4.6	16.8	18.4	14.1	9.5	20.0	22.1	16.9	11.7
200,000	154	8.8	10.0	7.2	4.6	16.0	17.8	13.6	9.4	19.1	21.1	16.3	11.5
	210	5.3	6.3	3.8	1.5	10.8	12.3	8.7	5.1	13.2	14.9	10.8	6.6
	264	2.2	3.0	1.0	−0.9	6.4	7.6	4.6	1.4	8.2	9.7	6.2	2.6
	66	18.8	20.5	16.1	11.7	30.6	32.2	26.5	19.9	35.7	38.6	31.1	23.5
	110	15.5	17.0	13.2	9.5	26.0	27.9	22.6	16.9	30.6	33.2	26.7	20.1
250,000	154	14.8	16.2	12.8	9.4	25.2	27.4	23.4	16.9	29.6	32.1	26.1	20.2
	210	10.4	11.7	8.7	5.8	18.7	20.6	16.1	11.6	22.3	24.5	19.3	14.1
	264	6.6	7.6	5.2	2.6	13.0	14.6	10.8	7.0	15.9	17.7	13.3	9.0

SUMMARY

The San Pedro wetfish-boat fleet has dwindled to half its size of 10 years ago. Large underused stocks of wetfish (jack mackerel and anchovies) exist in the California Current region. If these resources are to be harvested, the wetfish fleet must expand through the construction of new vessels or through the acquisition of surplus vessels from other fisheries. The purposes of the present study were to describe and document the financial condition of the fleet, to develop a model of wetfish-boat costs and earnings, and by means of this model, to examine the economic feasibility of fleet expansion and vessel replacement.

The findings of the study were that the fleet is antiquated, corporate profits are low, corporate net worth is low, working capital is inadequate, crew earnings are very low and are not increasing in pace with inflation, and employment in the fleet has decreased by 30 percent in the last 5 years.

Analysis of costs in several categories yielded equations to be used in predicting earnings at various levels of revenue and with various combinations of vessel size and composition of the catch. Their use showed that, of the four principal wetfish species, mackerel cost the least to land (per unit of value), anchovies and tuna cost about the same (more than mackerel) to land, and bonito cost the most to land.

Predicted crew earnings, profit, and return on investment based on the relations developed in the analysis of costs showed that although the expansion of the fleet through recruitment of existing vessels from other fisheries is feasible, fleet expansion or vessel replacement through construction of new vessels is not economically feasible at present rates of catch and prices of fish.

ACKNOWLEDGMENTS

Invaluable cooperation and assistance were provided in the data-gathering phase of this study by the following individuals and organizations: Fishermen's Cooperative Association of San Pedro (Anthony Pisano, Manager); Fishermen's Union, Local 33, I.W.L.U. (John J. Royal, Secretary-Treasurer); Seine and Line Fishermen's Union of San Pedro (Steven J. Hoinsky, Business Agent); Robinson, Pettie and Company; Rafalovich and Rafalovich, Public Accountants; Trani Realty; Steve Muskatelo, Public Accountant; Commercial Fishermen's Inter-Insurance Exchange; Star Kist Foods, Incorporated; Los Angeles County Assessor's Office; Marine Construction and Design Company; J. M. Martinac Shipbuilding Corporation; Tacoma Boatbuilding Company, Incorporated; Marine Resources Operations, California Department of Fish and Game; and others. Clark E. Blunt, Jr., James D. Messersmith, and Richard F. G. Heimann of the California Department of Fish and Game read the manuscript and made many helpful suggestions.

LITERATURE CITED

Ahlstrom, Elbert H.
1968. An evaluation of the fishery resources available to California fishermen. *In*: DeWitt Gilbert (editor), The future of the fishing industry of the United States, pp. 65-80. Univ. Wash. Publ. Fish., N.S. 4.

California Department of Fish and Game; Biostatistical Section, Marine Resources Operation.
1960a. The marine fish catch of California for the years 1957 and 1958. Calif. Dep. Fish Game, Fish Bull. 108, 74 pp.

California Department of Fish and Game; Biostatistical Section, Marine Resources Operations—Con.
1960b. The marine fish catch of California for the year 1959. Calif. Dep. Fish Game, Fish Bull. 111, 44 pp.

1961. The marine fish catch of California for the year 1960. Calif. Dep. Fish Game, Fish. Bull. 117, 45 pp.

1963. The California marine fish catch for 1961. Calif. Dep. Fish Game, Fish Bull. 121, 47 pp.

1964. The California marine fish catch for 1962. Calif. Dep. Fish Game, Fish Bull. 125, 45 pp.

1965. The California marine fish catch for 1963. Calif. Dep. Fish Game, Fish Bull. 129, 45 pp.

California Department of Fish and Game; Staff, Bureau of Marine Fisheries.
1949. The commercial fish catch of California for the year 1947 with an historical review 1916-1947. Calif. Div. Fish Game, Fish Bull. 74, 267 pp.

California Department of Fish and Game; Staff, Marine Fisheries Branch.
1954. The commercial fish catch of California for the year 1952 with proportion of king and silver salmon in California's 1952 landings. Calif. Dep. Fish Game, Fish Bull. 95, 64 pp.

1956. The marine fish catch of California for the years 1953 and 1954 with jack mackerel and sardine yield per area from California waters 1946-67 through 1954-55. Calif. Dep. Fish Game, Fish Bull. 102, 99 pp.

California Department of Fish and Game; Staff, Marine Resources Operation.
1958. The marine fish catch of California for the years 1955 and 1956 with rockfish review. Calif. Dep. Fish Game, Fish Bull. 105, 104 pp.

Croker, Richard S.
1938. Historical account of the Los Angeles mackerel fishery. Calif. Dep. Fish Game, Fish Bull. 52, 62 pp.

Green, Roger E., and Gordon C. Broadhead.
1965. Costs and earnings of tropical tuna vessels based in California. U.S. Fish Wildl. Serv., Fish. Ind. Res. 3: 29-45.

Greenhood, E. C.
1965. Statistical report of fresh, canned, cured, and manufactured fishery products for 1964. State Calif. Dep. Fish Game Circ. 29, 16 pp.

Greenhood, Edward C., and David J. Mackett.
1965. The California marine fish catch for 1964. Calif. Dep. Fish Game, Fish Bull. 132, 45 pp.

1967. The California marine fish catch for 1965. Calif. Dep. Fish Game, Fish Bull. 135: 1-42.

Heimann, Richard F. G., and Herbert W. Frey.
1968a. The California marine fish catch for 1966. Calif. Dep. Fish Game, Fish Bull. 138: 1-48.

1968b. The California marine fish catch for 1967. Calif. Dep. Fish Game, Fish Bull. 144, 47 pp.

Long, L. H.
1969. The world almanac and book of facts. Doubleday, New York, 934 pp.

McNeely, Richard L.
1961. The purse-seine revolution in tuna fishing. Pac. Fisherman 59: 27-58.

Roedel, Phil M.
1952. A review of the Pacific mackerel (*Pneumatophorus diego*) fishery of the Los Angeles region with special reference to the years 1931-1951. Calif. Fish Game 38: 253-273.

Scofield, W. L.
1951. Purse seines and other roundhaul nets in California. Calif. Dep. Fish Game, Fish Bull. 81, 83 pp.

United States Bureau of Customs.
1965. Merchant vessels of the United States 1965. U.S. Govt. Printing Office, Washington, D.C., 1314 pp.

MS. #2005

COMMERCIAL FEASIBILITY OF IRRADIATING HADDOCK AND COD FILLETS—1. QUALITY OF HADDOCK AS LANDED AT BOSTON, MASSACHUSETTS

by

John D. Kaylor and Edward J. Murphy

ABSTRACT

Successful commercial preservation of fresh fish fillets by irradiation requires that raw material of a level of quality suitable for irradiation be available. To determine the amount of haddock, *Melanogrammus aeglefinus*, landed in Boston by the New England offshore fleet that meet this level, we surveyed the Boston haddock fishery. About 78 percent of the haddock landed were of a level of quality high enough to warrant their being irradiated. Because haddock and cod, *Gadus morhua*, are handled similarly, this conclusion also applies to cod. Thus, the quality of fish would not be a problem in the irradiation preservation of fresh haddock and cod fillets.

CONTENTS

Authors: John D. Kaylor, *Supervisory Food Technologist*, and Edward J. Murphy, *Food Technologist*, Bureau of Commercial Fisheries Technological Laboratory, Emerson Avenue, Gloucester, Massachusetts 01930.

Published July 1970.

INTRODUCTION

As was indicated in our introductory paper (Kaylor and Murphy, 1970) to this series, the purpose of the work reported here was to determine the proportion of haddock landed at Boston that are fresh enough to warrant their being irradiated.

We report first on our experimental observations and then on a computer estimation of the correlations among our test data.

I. EXPERIMENTAL OBSERVATIONS

A. PROCEDURE

1. Method of Sampling

For the purpose of this survey, we were interested chiefly in the landings of the offshore fleet (medium-sized and large-sized trawlers), because the offshore trawlers stay out on the fishing banks longer than the smaller trawlers of the inshore fleet do. As a consequence, the offshore fleet lands a greater proportion of fish that are older in terms of the time that has elapsed since they are caught.

We tried two sampling plans — an on-ship plan and an on-wharf plan. Between both methods of sampling, we covered the important variations in seasonal temperature and were able to sample 34 percent of the medium-sized and large-sized trawlers of the Boston fishing fleet from one to five times each.

a. On-ship plan.—Our on-ship sampling plan, which was based upon statistical considerations, was as follows:

1. For trips of 20,000 to 40,000 pounds, take from each pen a sample consisting preferably of 25 fish but not less than 20 fish.
2. For trips of 40,000 to 60,000 pounds, take from each pen a sample consisting preferably of 20 fish but not less than 15 fish.
3. For trips of 60,000 to 100,000 pounds, take from each pen a sample consisting preferably of 15 fish but not less than 10 fish.

We tried this sampling plan for three trips each of Trawlers 1 and 6 and part of one trip of Trawler 2 (Table 1) in the winter.

b. On-wharf plan.—Subsequently, we adopted a different method of sampling — one that we did on the wharf rather than in the hold of the trawler. This method was as follows:

1. Take, at random, a haddock dumped into the weigh box from the canvas discharge basket of the trawler.
2. Examine the fish objectively and subjectively.
3. Continue examining the fish until all the fish have been unloaded.

We started this method of subsequently sampling in summer and continued it into autumn.

2. Method of Testing

We determined the temperature of the fish and the quality of the fish, as follows:

a. Temperature.—The temperatures of the haddock caught in the winter were measured in the hold of the trawlers as the fish pens were broken down prior to unloading the fish from the vessel. The temperatures of fish caught in the summer and autumn were measured at the point of discharge from the trawler into weigh boxes on the wharf.

We measured the temperatures by inserting stainless-steel temperature-sensing probes into each haddock, immediately forward of the first dorsal fin and through the thick fleshy portion down to the backbone and about half an inch along the side of it. Each probe was con-

Table 1.—Freshness survey of haddock landed at Boston 1965

Trawler Number	Date	Fish sampled	Temperature	Organoleptic etsimation					
				Damage	Skin	Eyes	Gills	Texture	Odor
		Number	° *F.*	*Scale of 1-4, with 1 being the highest value*					
1	Jan. 12	63	32.2	1.1	2.0	2.0	2.4	2.0	2.3
	Jan. 26	80	32.4	1.1	1.6	1.5	1.8	1.8	1.9
	Feb. 8	90	32.8	1.1	1.0	1.7	1.8	1.7	1.9
	Sept. 9	180	35.4	1.6	2.0	1.9	2.0	2.0	1.9
	Sept. 22	160	35.4	1.8	2.2	2.5	2.7	2.5	2.5
2	Feb. 9	32	32.2	1.0	1.0	1.1	1.5	1.5	1.8
	Aug. 31	120	34.0	1.6	2.1	2.5	2.6	2.6	2.4
	Sept. 13	180	34.7	1.6	1.9	2.1	2.2	2.0	2.0
	Oct. 5	111	33.6	2.0	2.2	2.6	2.6	2.6	2.4
	Nov. 1	65	35.3	2.0	2.2	2.4	2.2	2.2	2.2
3	Aug. 30	180	34.0	1.6	2.1	2.3	2.6	2.5	2.3
	Sept. 8	180	35.4	1.6	2.1	2.1	2.3	2.1	1.9
	Sept. 28	160	33.9	2.2	2.1	2.4	2.4	2.6	2.3
	Oct. 13	105	33.6	2.0	2.1	2.4	2.5	2.4	2.2
	Nov. 3	65	34.6	1.8	2.3	2.6	2.8	2.9	2.4
4	Aug. 26	60	36.2	1.7	2.1	2.4	2.5	2.5	2.3
	Oct. 6	109	32.8	2.0	2.1	2.1	2.3	2.3	2.2
	Oct. 18	131	34.3	1.8	2.0	2.1	2.2	2.1	2.0
	Oct. 28	15	34.0	1.7	1.4	1.4	1.7	1.7	1.6
5	Sept. 7	160	36.3	1.5	2.1	2.2	2.4	2.3	2.2
	Sept. 16	100	34.1	1.7	2.1	2.2	2.4	2.2	2.3
	Sept. 27	100	34.3	1.9	2.1	2.4	2.5	2.4	2.4
	Oct. 7	85	32.8	2.1	2.1	2.2	2.2	2.3	2.2
6	Jan. 18	46	32.4	1.3	2.0	2.0	2.0	2.1	2.0
	Feb. 1	62	32.8	1.0	1.0	1.5	1.5	1.7	1.7
	Feb. 10	80	33.7	1.0	1.0	1.8	1.9	1.9	2.0
7	Aug. 23	160	36.0	1.6	2.1	2.9	2.9	2.6	2.5
	Sept. 23	60	37.4	1.6	2.1	2.4	2.2	2.2	2.2
	Oct. 11	107	34.6	1.9	1.8	1.8	1.8	2.0	1.7
8	Aug. 27	172	34.2	1.8	2.1	2.4	2.5	2.7	2.2
	Sept. 2	160	33.7	1.3	1.9	1.8	2.1	2.2	1.9
	Nov. 4	120	36.6	1.8	2.0	1.7	1.7	1.9	1.6
9	Aug. 27	120	36.1	1.6	2.0	2.3	2.6	2.6	2.2
	Oct. 4	107	33.4	1.9	2.2	2.4	2.2	2.3	2.2
10	Oct. 8	100	33.5	1.8	2.0	2.1	2.2	2.2	1.9
	Nov. 2	71	33.2	2.1	2.3	2.5	2.6	2.7	2.4
11	Aug. 24	150	34.9	1.9	2.1	2.4	2.9	3.0	2.6
12	Oct. 14	100	34.0	2.1	2.1	2.0	2.1	2.1	1.9
13	Sept. 1	160	33.9	1.6	2.1	2.3	2.5	2.5	2.2
14	Sept. 3	92	33.0	1.3	1.8	1.7	2.0	1.9	1.5
15	Oct. 15	100	--	1.9	2.1	1.8	1.8	2.1	1.8
16	Oct. 22	80	34.1	1.8	1.8	1.6	1.8	1.6	1.8
17	Oct. 21	16	35.0	1.2	1.2	1.4	1.2	1.4	1.4
Total		4,594	4,494						
Average				1.6	1.9	2.1	2.2	2.2	2.0

nected to a Model 42 SF Tele-Thermometer (Yellow Springs Instrument Co.).[1] This instrument has an accuracy of ±1° F. in the range of —40° F. to 302° F. We allowed the instrument to come to equilibrium before we recorded the temperature reading.

[1] The use of trade names is merely to facilitate descriptions of the exact experimental procedure; no endorsement of commercial products is implied.

b. Quality.—Described in this section are the criteria of quality we used and the basis for acceptance or rejection of a trip for the purposes of this survey.

(1) Criteria of quality used.—In planning the survey, we tried to develop suitable criteria for freshness and other quality characteristics. The criteria we chose consisted of

only four categories, which were assigned numerals indicating their relative score values. In the criteria, only the very freshest or perfect fish were assigned a value of 1 for each organoleptic characteristic such as damage, skin, eyes, and gills; the lowest quality fish were assigned a value of 4 for the corresponding characteristics. Table 2 shows the detailed criteria.

The classification of quality characteristics into only four categories had two advantages. First, it was based on a system that, in previous work, we had found successfully describes the changes taking place in the fish as they age. Second, the system could readily be adapted for use in automatic data processing.

(2) Basis used for acceptance or rejection of a trip load.—Organoleptic examinations formed the basis for all our judgments of acceptance or rejection. Although we recorded six subjective factors (Table 1), we used only the last four of these factors (eyes, gills, texture, and odor) to decide whether to accept or reject a trip load.

To decide on the proportion of haddock of a freshness level suitable for irradiation processing, we had to adopt certain cut off points. On the basis of past work, we decided that haddock (and scrod haddock) would be acceptable if:

1. The average score for appearance of eyes, color of gills, texture of flesh, and odor of gill cavity was less than 2.5.
2. The average score for odor of gill cavity did not exceed 2.3.
3. Less than 1 percent of the fish samples had a score of 4 for both color of gills and odor of gill cavity.

B. RESULTS

1. Temperature

Table 1 shows the results of the temperature measurements on a trip basis, and Table 3 summarizes the data on a seasonal basis. The temperature of fish caught in the winter is definitely lower than that of fish caught in the summer or in the autumn, but the difference is small.

2. Quality

Reported here are (a) the number of trips "rejected" on the basis of quality and (b)

Table 2.—Organoleptic criteria for judging fresh fish

Factor	Rating	Characteristics
Damage to the whole fish	1	No physical damage. Skin intact (except for evisceration cuts).
	2	Slight damage or suffusion of blood under the skin. Minor break in skin surface.
	3	Fork holes or torn flesh evident. Crushed. Belly blown with some viscera visible in whole fish.
	4	Badly torn or crushed. Belly blown with viscera protruding in whole fish.
Condition of the skin surface	1	Skin surface has high sheen, not faded. Moderate amount of clear, evenly distributed slime. Whole appearance bright as though alive.
	2	Skin surface somewhat faded in luster. Slime thicker and beginning to become opaque.
	3	Skin faded, dull. Scales loose. Slime thick and opaque.
	4	Skin very faded. Very dull. Scales loose and detach easily. Slime thick, opaque, and knotted or ropy.
Appearance of the eyes	1	Clear, bright, slightly protruding to bulging (depending on species), black pupil, transparent cornea.
	2	Cornea slightly cloudy, slightly dull, not protruding. Pupil tending to become cloudy.
	3	Dull, flat, or commonly sunken. Cornea opaque. Pupil definitely cloudy or milky.
	4	Sunken, very dull. Cornea discolored — reddish or yellowish. Pupil opaque.
Color of the gills	1	Bright to dark red to bright pink, depending on species. Free of slime. No odor.
	2	Less color intensity. Dull red to pink. Slightly slimy. May have slight odor.
	3	Pink to pale pink. Slimy. Number 3 odor classification (see Odor).
	4	Faded pink, to discolored, tan yellow, grey, or brown. Number 4 odor classification (see Odor).
Texture of the flesh	1	Flesh very firm and elastic (in rigor mortis — body rigid). Indented finger marks disappear readily.
	2	Flesh losing elasticity. Indented finger marks disappear slowly.
	3	Flesh moderately soft. Resiliency lost. Pressure marks remain.
	4	Flesh soft and limp. Pits readily on being pressed.
Odor of the gill cavity	1	Odor characteristic of freshly caught fish of the particular species.
	2	Practically no odor. Neutral or very faint fishy odor.
	3	Slight fishy odor.
	4	Strong fishy, ammoniacal, or other repugnant odors associated with decomposition in varying degrees.

Table 3.–Seasonal difference of haddock landings at Boston 1965

Season	Trips	Samples	Average of all measurements of each factor						
			Temperature	Subjective data on:					
				Damage	Skin	Eyes	Gills	Texture	Odor
	No.	*No.*	*° F.*	— Subjective evaluation on a scale of 1 to 4 —					
Winter	7	453	32.6	1.1	1.4	1.5	1.8	1.8	2.0
Summer	15	2,174	34.8	1.6	2.0	2.2	2.4	2.4	2.2
Autumn	21	1,967	34.3	1.9	2.0	2.1	2.2	2.2	2.0

Note: See Table 2 for a definition of the subjective evaluation.

the seasonal variation in the quality of the haddock.

a. Number of trips rejected.—For our purpose, we rejected nine complete trawler landings even though most of the fish in each trip would have passed inspection according to our criteria. Only 1 haddock scoring 4 on the basis of gills and odor could negate the entire trip if less than 100 fish were sampled. Occasionally, no fish had a score of 4 for both gills and odor, but we rejected the entire trip simply because the general level of freshness as judged by the condition of the eyes, gills, texture, and odor was too low by our standard.

This rejection does not mean that the fish were unfit for consumption or that they violated food laws. Instead, it means that, although the fish were acceptable for immediate consumption or freezing, most of them had been caught for too long a time to permit them to have as long a shelf life after irradiation as fresher fish would.

b. Seasonal variation in quality.—Table 3 summarizes the data on quality according to season. In every category, the quality of fish caught in the winter was superior to that of those caught in the summer and in the autumn.

II. COMPUTER ESTIMATION OF CORRELATIONS AMONG TEST DATA

When this survey was begun, we were interested in determining what correlation, if any, we would find, with the aid of a computer, (1) between organoleptic evaluations and temperature and (2) among all six organoleptic factors, each one against the remaining five.

A. PROCEDURE

The data from each trawler trip were punched on a card and fed into a computer that had been programed to give correlations, first on a trip basis and then on the basis of one large population instead of on the basis of 34 separate populations.

B. RESULTS

1. Trip Basis

When the data were programed on a trip basis, the results were inconclusive, because the differences among the factors of each trip were not large enough for the computer to distinguish.

2. One-Large-Population Basis

When the data were programed on the basis of one large population, however, the results were strikingly different. By means of the data obtained with the aid of the computer, we now found differences that only a skilled fish inspector could recognize before.

a. Correlations of organoleptic evaluations with temperature.—The temperatures were quite uniformly low (Table 1), and the difference between winter and summer temperatures (Table 3) was relatively small. Nevertheless, the computer showed a correlation between organoleptic score and temperature that was significant at the 1-percent level of probability.

b. Correlations within the group of six organoleptic factors studied.— The highest degrees of correlation was found within the group of the six organoleptic factors. In this group, the lowest correlations were between damage and the remaining five organoleptic factors and between skin and the remaining five organoleptic factors.

This result supported our original choice of using only four factors (eyes, gills, texture, and odor) upon which to pass final judgment to accept or reject trips as shown in Table 1. Furthermore, the data obtained with the computer agreed completely with what skilled inspectors have maintained are the two most reliable factors of all — appearance of the gills and odor. The correlation between these two factors was highly significant, indicating a value that is larger than would be expected by chance at the 1-percent level of probability.

SUMMARY

We surveyed haddock landings in Boston, Massachusetts, to determine whether the level of freshness was high enough to warrant the use of radiation to extend the shelf life of fresh fillets.

The survey was made during the winter, summer, and autumn so as to reflect the effect of temperature differences of the principal seasons, with spring and autumn being considered equivalent. Criteria for subjective measurements of freshness were developed and applied to over 4,500 individual samples of haddock. Objective measurements of temperature were made by Tele-Thermometer.

All data were fed into a computer that was programed to give correlations among the temperature measurements and the expert subjective judgments. The computer showed that subjective examinations had significant to highly significant correlations at the 1-percent level of probability, but the judgment of highly skilled fish examiners was superior to the findings of the computer in distinguishing and recording fine distinctions.

CONCLUSIONS

During the winter, summer, and autumn of 1965, 78.6 percent of the haddock examined by us at the Boston Fish Pier was fresh enough to justify the use of irradiation. Because haddock and cod are handled alike, this conclusion also applies to cod. Thus, the freshness of fish would not be a problem in the irradiation preservation of haddock and cod fillets.

ACKNOWLEDGMENT

This work was supported in its entirety by the United States Atomic Energy Commission under Contract Number AT(49-11)-1889.

LITERATURE CITED

Kaylor, John D., and Edward J. Murphy.
1969. Commercial feasibility of irradiating haddock and cod fillets: Introduction. U.S. Fish Wildl. Serv., Fish. Ind. Res. 6: 1-3.

MS. #1992

COMMERCIAL FEASIBILITY OF IRRADIATING HADDOCK AND COD FILLETS—2. TEMPERATURE PATTERNS DURING SHIPMENTS OF FRESH FILLETS BY TRUCK AND BY RAIL

by

John D. Kaylor and Edward J. Murphy

ABSTRACT

For fresh haddock and cod fillets to be irradiated and shipped commercially to distant points in the United States, the fillets must be kept near the temperature of ice during distribution. To check on the temperatures to be expected, we surveyed the principal methods of commercial distribution of fresh fishery products. We found that present commercial methods of distributing fresh haddock fillets result in fillet temperatures that average less than 40° F., a temperature that would be sufficiently low to permit shipment of irradiated fillets to the most distant parts of the country.

CONTENTS

Authors: John D. Kaylor, *Supervisory Food Technologist*, and Edward J. Murphy, *Food Technologist*, Bureau of Commercial Fisheries Technological Laboratory, Emerson Avenue, Gloucester, Massachusetts 01930.
Published July 1970.

INTRODUCTION

The ultimate goal in the present series of studies was to determine whether it is commercially feasible to irradiate fresh cod and haddock fillets for shipment by common carrier to distances well beyond present-day markets, and keep them at a high level of freshness.

To ensure a minimum expenditure of experimental funds, we decided that the first step in this study was to determine what proportion of fresh haddock landed at Boston, Massachusetts, has the high quality that would justify irradiation. This study showed that about 78 percent of the haddock (and presumably also of cod) were suitable for this purpose and that the quality of fresh cod and haddock therefore would not be a limiting factor.

To ensure further a minimum expenditure of funds, we decided to determine whether temperatures of fillets in channels of commercial distribution would be a limiting factor. The purpose of the work reported in this paper, therefore, was to determine patterns of temperature that would be encountered during commercial shipment of fresh fillets by truck and by rail from Massachusetts fishery centers to distant markets.

I. SHIPMENT BY TRUCK

Shipments by truck were of four kinds: (A) processor-distributor shipments, (B) frozen-food shipments, (C) refrigerated fresh-fish shipments, and (D) nitrogen-gas refrigerated shipments.

A. PROCESSOR-DISTRIBUTOR SHIPMENTS

1. Procedure

Described here are: (a) preparation of the samples, (b) recording of the data, (c) types of shipping containers used, and (d) methods of shipment.

a. Preparation of samples.— To measure the temperature of fillets that are transported by common carrier, we obtained the permission and cooperation of fishery firms to use their regular commercial shipments of fillets. In addition, we purchased haddock fillets on the open market and shipped them under commercial conditions to supplement the data gained from the industry shipments.

The internal temperature of the fillets was obtained by inserting sterilized temperature-sensing probes into the center of fillets wrapped in cellophane and packed in fillet cans or in fibre boxes, with the wire leads running to the outside of the bulk shipping containers. These containers were wooden barrels or wooden boxes, depending upon the distance the fish were to be shipped. This arrangement required us to enter the vehicle to record the temperatures. In some instances, however, we were able to use long wire leads run from the shipping containers through the truck-body drain holes to the outside of the trailer. The second arrangement permitted us to read and record fillet temperatures without opening trailer doors during shipment. Normally, the trailer doors are not opened until the trailer arrives at its destination.

b. Recording of data.— The temperature was measured with a widespan transistorized thermometer (YSI Model 42SF Tele-Thermometer[1]), which was carefully calibrated before each shipment. It had an accuracy of ±1° F. and a range from —40° F. to +302° F., divided into three subranges. Temperatures of the air in the vehicle were obtained by means of a bimetallic spring-wound, 7-day recording thermometer with a circular paper chart. Outside air temperatures were obtained by means of a general-purpose, all-metal thermometer in which the temperature-sensing element was a bimetallic double helix coil. A Bureau of Commercial Fisheries food technologist accompanied each shipment from the originating shipping point to the city of destination. His

[1] The mention of trade names is merely to facilitate description; no endorsement is implied.

duties were to record the temperatures of the fillets, make observations on handling practices, and ship the fillets back to Gloucester by air for further testing. The methods of distribution we studied reflected widespread industry practices, and we made the shipments to embrace the extremes of temperature conditions to be found in present and prospective market areas.

c. Types of shipping containers.— Fresh fillets are shipped most commonly in 10-, 20-, or 30-pound-capacity oblong metal cans or, less commonly, in waxed fibreboard containers of 10- or 20-pound capacity. These containers are buried in ice inside bulk shipping containers of two types. The most common bulk shipping container is a wooden box that will hold five 20-pound containers and about 80 pounds of ice. This wooden container is being replaced, to a small extent, by a heavily waxed fibreboard container. Both the wooden and fibreboard containers are shipped exclusively by truck. The second type of shipping container is a wooden barrel that is capable of holding five 20-pound fillet cans and about 150 pounds of ice.

When the fillets are packed in boxes, they are always shipped in insulated, refrigerated trucks to destinations usually located no farther from Boston than cities in Kentucky and Ohio. When the fillets are packed in barrels, they are shipped to more distant points, such as cities in Texas, and are transported entirely by rail in noninsulated, nonrefrigerated freight cars along with general merchandise. Because of the longer distances to which they are shipped, the barrels are re-iced one or more times in transit, depending upon the temperature and the distance of the destination to which the shipment is being made.

d. Methods of shipment.—Formerly, some fish processors acted as their own distributors, although comparatively few such individuals are active in the industry now. The distributor whose operation we studied has a small fleet of trucks and makes sales in Western Massachusetts and nearby Eastern New York. Round trips are made weekly in well-insulated, two-compartmented trucks in good physical condition and take about a day. Fresh seafoods, which are carried in the forward compartment, are invariably well iced. No mechanical refrigeration is available in this compartment, so ice is the sole means of refrigeration. The doors to the fresh-seafood compartment may be opened as many as 30 times during deliveries. Frozen foods are carried in the rear compartment where the temperature is maintained by an electrical system of refrigeration.

2. Results

Table 1 indicates that, in general, the temperature of fresh fillets at the beginning of any trip are higher than desirable (over 40° F.). Although the temperature of the fillets generally drops by the end of the sales-distribution trip, the interval is too short (less than a day) to achieve the most desirable cooling effect by means of ice alone.

B. FROZEN-FOOD SHIPMENTS

1. Procedure

Long-distance hauls of fresh fillets are made in well-insulated mechanically refrigerated

Table 1.—Temperature of fresh haddock fillets shipped by processor's truck from Gloucester, Massachusetts, to the Albany, New York, area, 1965

Month	Weight of fillets shipped	Length of time fillets were in transit	Temperature of fillets at: Start of trip, Maximum	Start of trip, Minimum	Start of trip, Average	End of trip, Maximum	End of trip, Minimum	End of trip, Average
	Pounds	*Hours*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
January	2,500	27	54	44	50.0	33	33	33.0
January	3,000	26	48	41	44.2	38	35	36.6
July	4,500	22	50	42	45.1	39	39	39.0
September	3,500	22	56	48	52.0	42	42	42.0
November	2,000	20	44	39	42.5	41	37	39.0

Note 1: The truck was insulated but was not refrigerated.
Note 2: The average temperatures shown were the averages of 60 recordings per trip.

trailer trucks, which carry frozen seafoods as the main cargo to points as far as Florida. These vehicles carry the frozen seafoods in the main section of the mechanically refrigerated trailer and carry the boxed iced fish in small portion of the rear of the trailer. Usually, the frozen and fresh seafoods are separated by a canvas or plastic drop curtain or sometimes by 4-inch insulated wall. The trips to Florida commonly take 5 or 6 days, depending on the number of delivery stops the driver must make.

A common feature of this method of shipment by truck is that the fresh fillets at the rear of the trailer become partly frozen by the time the vehicle arrives in Northern Florida. At this point, the fresh fillets are usually transferred to a different truck that is used exclusively for delivery of fresh food products. The partly frozen fresh fillets are allowed to thaw before final delivery.

2. Results

Table 2 shows that the temperature of fresh fillets is always lowered to below 32° F. regardless of the initial temperature of fillets.

C. REFRIGERATED FRESH-FISH SHIPMENTS

1. Procedure

Fresh seafoods exclusively are shipped several times a week from Boston to Ohio cities in well-insulated, mechanically refrigerated trailer trucks. Fresh fillets cans are buried in ice in wooden boxes or in heavily waxed fibreboard boxes. The covers of the wooden boxes are fastened securely by nails, and those of the fibreboard boxes are fastened by wire strapping. Throughout the trip, the temperature of the air in the trailer is maintained at about 28° F. by means of mechanical refrigeration. The combination of ice immediately surrounding the fillet containers and the mechanically refrigerated air in the trailer ensure that the temperature of the fillets is maintained at slightly above the freezing point of the fillets.

2. Results

Table 3 shows that this method of transportation always succeeds in lowering the temperature of the fresh fillets to ideally low levels by the time the shipment arrives at the city of destination. This lowering invariably occurs regardless of the temperature of the fillets at the start of the trip.

D. NITROGEN-GAS REFRIGERATED SHIPMENTS

1. Procedure

Substantial amounts of fresh fillets (chiefly flounder) are shipped from New Bedford, Massachusetts, in insulated, nitrogen-gas refrigerated trailer trucks. We wished to compare the temperature pattern of this method of distribution against that of the dominant

Table 2.—Temperature of fresh haddock fillets shipped by frozen-food truck from Gloucester, Massachusetts, to Miami, Tampa, and Jacksonville, Florida, 1965

Month	Weight of fillets shipped	Length of time fillets were held:		Temperature of fillets at:					
				Start of trip			End of trip		
		At MPDI	In transit	Maximum	Minimum	Average	Maximum	Minimum	Average
	Pounds	*Hours*	*Hours*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
February	240	--	117	39	37	37.5	19	16	17.5
March	240	--	120	53	46	49.0	28	26	27.9
May	160	--	119	42	36	38.8	32	30	31.0
May	160	--	119	41	35	38.2	30	28	29.2
August	100	--	119	46	42	43.7	30	24	28.0
September	100	--	137	47	42	44.8	20	19	19.5
October	160	22	113	42	33	36.0	24	23	23.2
November	100	19	77	50	49	49.5	31	30	30.5

Note 1: The truck was refrigerated and insulated; the minimum load was 24,000 pounds.
Note 2: MPDI (Marine Products Development Irradiator, Bureau of Commercial Fisheries, Gloucester, Massachusetts)
Note 3: The average temperatures shown were the averages of 111 recordings per trip.

refrigerated fresh-fish shipments by mechanically refrigerated truck. Shipments from New Bedford are made in round fillet cans rather than in the customary oblong fillet cans. The round cans have soldered side seams to make them watertight, because the custom for nearly 30 years has been to add about a pint of brine to the containers immediately before they are closed. These fillet cans are buried in ice as are the oblong fillet cans.

2. Results

Table 4 shows the temperature pattern of a commercial shipment of flounder fillets from New Bedford, Massachusetts, to Baltimore, Maryland. Although the temperature of the trailer is uniformly low, the temperatures of the fillets are not as low as are those found in the conventional mechanically refrigerated trailer trucks that are used exclusively for hauling shipments of fresh fishery products.

Table 3.—Temperature of fresh haddock fillets shipped by refrigerated fresh-fish trucks from Boston, Massachusetts, to Cleveland, Ohio, 1965

Month	Weight of fillets shipped	Length of time fillets were held		Temperature of fillets at:					
				Start of trip			End of trip		
		At MPDI	In transit	Maximum	Minimum	Average	Maximum	Minimum	Average
	Pounds	Hours	Hours	° F.	° F.	° F.	° F.	° F.	° F.
March	240	--	67	42	38	39.0	32	30	30.9
March	240	--	66	44	32	39.4	31	28	29.6
April	240	--	66	46	45	45.1	32	30	31.4
June	240	--	66	52	48	49.6	32	31	31.6
August	240	3	66	62	51	54.8	29	29	29.0
November	240	--	66	39	34	37.2	32	30	30.8

Note 1: The truck was refrigerated and insulated; the minimum load was 24,000 pounds.
Note 2: MPDI (Marine Products Development Irradiator, Bureau of Commercial Fisheries, Gloucester, Massachusetts).
Note 3: The average temperatures shown were the averages of 108 recordings per trip.

Table 4.—Temperature of fresh flounder fillets shipped by nitrogen-gas refrigerated truck from New Bedford, Massachusetts, to Baltimore, Maryland, 1966

Month	Weight of fillets shipped	Length of time fillets were in transit	Temperature of fillets at:					
			Start of trip			End of trip		
			Maximum	Minimum	Average	Maximum	Minimum	Average
	Pounds	Hours	° F.	° F.	° F.	° F.	° F	° F.
April	240	48	42	40	41	47	32	40

Note 1: The truck was refrigerated and insulated; the minimum load was 20,000 pounds.
Note 2: The average temperatures show the averages of 60 recordings.

II SHIPMENT BY RAIL

The oldest commercial method of interstate distribution of fresh fillets is by rail. We made rail shipments from Boston, Massachusetts, to three cities: Jacksonville, Florida; Texarkana, Texas; and Seattle, Washington.

A. SHIPMENT TO JACKSONVILLE, FLORIDA

1. Procedure

The preparation of samples and the recording of data were identical for both truck and rail shipments. The containers for rail shipments differed from those used in truck shipments. We followed the customary industry practice of placing five 20-pound fillet cans in a wooden barrel with about 150 pounds of ice. The top of each barrel was covered with a specially treated combination of plastic and burlap to provide a flexible cover, which was coopered in place.

The barrels were shipped by regular noninsulated, nonrefrigerated railway freight cars that carry general freight. The temperature of the air in the cars frequently rose into the 80's and 90's Fahrenheit. The barrels, therefore, were re-iced in transit one or more times, depending upon the amount of ice that was

melted. The flexible covers of the barrels aid re-icing in transit, whereas wooden boxes with covers that are nailed fast are too inconvenient to re-ice.

2. Results

Table 5 shows how effectively this method of distribution operates either to maintain fillets at initially low temperatures or to prevent excessive rise of temperature during the hot season.

B. SHIPMENT TO TEXARKANA, TEXAS

1. Procedure

All shipments by rail were made in barrels as described in the preceding procedure.

2. Results

Table 6 shows how effectively desirable low temperatures (less than 40° F.) are maintained with this relatively primitive method of distribution.

C. SHIPMENT TO SEATTLE, WASHINGTON

1. Procedure

All shipments by rail were made in barrels as previously described.

2. Results

Table 7 shows that during long shipments of about 4 to 5 days, the rise in temperature of the fillets is slight and well below the borderline temperature of 40° F.

Table 5.—Temperature of fresh haddock fillets shipped by rail from Boston, Massachusetts, to Jacksonville, Florida, 1965

Month	Weight of fillets shipped	Length of time fillets were held		Temperature of fillets at:					
				Start of trip			End of trip		
		At MPDI	In transit	Maximum	Minimum	Average	Maximum	Minimum	Average
	Pounds	*Hours*	*Hours*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
January	120	72	38	32	32	32.0	34	33	33.3
May	120	78	39	34	33	33.3	34	33	33.8
August	100	92	44	34	33	33.3	37	33	36.0
October	100	74	38	36	32	33.5	34	33	33.2

Note 1: The general freight car was nonrefrigerated and noninsulated.
Note 2: MPDI (Marine Products Development Irradiator, Bureau of Commercial Fisheries, Gloucester, Massachusetts).
Note 3: The average temperatures shown were the averages of 55 recordings per trip.

Table 6.—Temperature of fresh haddock fillets shipped by rail from Boston, Massachusetts, to Texarkana, Texas, 1965 and 1966

Month	Weight of samples shipped	Length of time fillets were held		Temperature of fillets at:					
				Start of trip			End of trip		
		At MPDI	In transit	Maximum	Minimum	Average	Maximum	Minimum	Average
	Pounds	*Hours*	*Hours*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
April	200	--	50	40	33	37.4	36	34	34.4
April	200	--	49	39	36	37.6	33	33	33.0
July	200	--	49	39	32	35.9	44	35	38.0
October	200	72	51	36	35	34.6	33	33	33.0
December	200	75	52	34	34	34.0	34	34	34.0
February	200	73	51	34	33	33.2	34	33	33.5

Note 1: The general freight car was nonrefrigerated and noninsulated.
Note 2: MPDI (Marine Products Development Irradiator, Bureau of Commercial Fisheries, Gloucester, Massachusetts).
Note 3: The average temperatures shown were the averages of 96 recordings per trip.

Table 7.–Temperature of fresh haddock fillets shipped by rail from Boston, Massachusetts, to Seattle, Washington, 1965 and 1966

Month	Weight of fillets shipped	Length of time fillets were held:		Temperature of fillets at:					
				Start of trip			End of trip		
		At MPDI	In transit	Maximum	Minimum	Average	Maximum	Minimum	Average
	Pounds	*Hours*	*Hours*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*
September	300	73	91	33	33	33.0	35	34	34.4
October	600	70	111	33	32	32.7	35	33	34.6

Note 1: The general freight car was nonrefrigerated and noninsulated.
Note 2: MPDI (Marine Products Development Irradiator, Bureau of Commercial Fisheries, Gloucester, Massachusetts).
Note 3: The average temperatures shown are the averages of 139 recordings per trip.

SUMMARY

Before embarking on a costly program of research to test the commercial feasibility of irradiating haddock and cod fillets, we wanted to determine whether or not some practice in the industry would preclude the success of irradiating fish. We particularly wanted to know two things: (1) whether the haddock being landed in Boston, Massachusetts, are sufficiently fresh to warrant their being irradiated to extend their shelf life and (2) whether the temperature of the fillets when shipped by common carrier is sufficiently low to ensure that irradiated fillets will arrive at distant points in the nation in a fresh condition.

The first study in the series showed that the freshness level of haddock was more than adequate.

The study reported here looked into the problem of temperature of fresh fillets being shipped by common carriers. We investigated, during all seasons of the year, the temperature of fresh fillets shipped by two means of transportation: truck and train.

We found that shipments by truck could be divided into four categories: (1) processor-distributor shipments, (2) frozen-food shipments, (3) refrigerated fresh-fish shipments, and (4) nitrogen-gas refrigerated shipments.

One method of shipping by truck for short distances was found to be too short in duration to achieve the maximum cooling of fresh fillets under the conditions of shipment. Shipment by refrigerated trucks designed for transportation of frozen foods resulted in partial freezing of the fresh fillets. The most common method of shipping fresh fishery products using a combination of ice and mechanical refrigeration maintained the fresh fillets at optimum temperatures. One study of a more recent method of truck refrigeration using nitrogen gas showed that it had no advantage over the dominant method of refrigeration.

Three studies of shipment by rail showed that fresh fillet temperatures were maintained at optimum temperatures by a method of refrigeration that has been in long use — namely, shipment of the fresh fillets in cans packed in ice in wooden barrels, which are re-iced enroute when needed.

CONCLUSIONS

The survey showed that all the common commercial methods of transporting fresh fish interstate ensure fillet temperatures of 40° F. or lower. This temperature would be sufficiently low to permit shipment of irradiated fresh fillets in good condition to the most distant parts of the continental United States.

ACKNOWLEDGMENTS

The geographical extent of this survey was so great that the survey could not have been accomplished without the advice and cooperation of various fishery industrial firms and transportation agencies. Those who participated in this project were: National Fish Division of A&P Food Stores, P. J. Markos Seafood Company, Railway Express Agency Incorporated, Greenleaf Motor Express, Harriet Transport Incorporated, Refrigerated Food Express Incorporated, and Sea-Cold Service Incorporated.

This work was supported in its entirety by the United States Atomic Energy Commission under Contract AT(49-11)-1889.

MS. #2038

AUTHOR INDEX OF PUBLICATIONS AND ADDRESSES -- 1968

BUREAU OF COMMERCIAL FISHERIES BRANCH OF TECHNOLOGY AND BRANCH OF REPORTS (SEATTLE)

by

Helen E. Plastino and Mary S. Fukuyama

PUBLICATIONS

Ampola, Vincent G., and Louis J. Ronsivalli. Effect of special handling of haddock on postirradiation shelf life of haddock fillets. U.S. Fish Wildl. Serv., Fish. Ind. Res. 4: 109-111.

Anderson, Margaret L., and Elinor M. Ravesi. Relation between protein extractability and free fatty acid production in cod muscle aged in ice. J. Fish. Res. Bd. Can. 25: 2059-2069.

Barnett, H., and R. W. Nelson. Using the Cotlove titrator for measuring chloride in marine products. Food Technol. 22(6): 139-141.

Brooke, R[ichard] O., J[oseph] M. Mendelsohn, and F[rederick] J. King. Significance of dimethyl sulfide to the odor of clam meats. Inst. Food Technol., 28th Annu. Meet., Pap. 89, 97-98.

Significance of dimethyl sulfide to the odor of sòft-shell clams. J. Fish. Res. Bd. Can. 25: 2453-2460.

Bureau of Commercial Fisheries Technological Laboratory, Ann Arbor, Michigan, Staff. An action program to demonstrate the feasibility of introducing new techniques in the Lake Superior commercial fishing industry. U.S. Dep. Commer., Econ. Develop. Admin., Tech As. Proj. 1083, 97 pp.

Bureau of Commercial Fisheries Technological Laboratory, Gloucester, Massachusetts, Staff. Improving and expanding the distribution of fresh (unfrozen) seafoods by means of insulated containers. Commer. Fish. Rev. 30(3): 39-42.

Burkholder, L., P. R. Burkholder, A. Chu, N. Kostyk, and O. A. Roels. Fish fermentation. Food Technol. 22(10): 1278ff.

Carroll, B. J., G. B. Reese, and B. Q. Ward. Microbiological study of iced shrimp: Excerpt from the 1965 iced-shrimp symposium. U.S. Fish Wildl. Serv., Circ. 284, 17 pp.

Carver, Joseph H., Thomas J. Connors, Louis J. Ronsivalli, and John A. Holston. Shipboard irradiator studies. U.S. AEC, Tech. Inform., TID-24332, 34 pp. and Addendum, 10 pp.

Christiansen, Lee N., Janet Deffner, E. M. Foster, and H. Sugiyama. Survival and outgrowth of *Clostridium botulinum* type E spores in smoked fish. Appl. Microbiol. 16: 133-137.

Authors: Helen E. Plastino, *Administrative Clerk*, and Mary S. Fukuyama, *Editor*, Bureau of Commercial Fisheries Division of Publications, Building 67, U.S. Naval Air Station, Seattle, Washington 98115.
Published July 1970.

Clem, Joe P., and E. Spencer Garrett.
Sanitation guidelines for the breaded-shrimp industry. U.S. Fish Wildl. Serv., Circ. 308, 14 pp.

Connors, Thomas J., and Daniel W. Baker.
Vacuum evisceration, a modern method of cleaning fish at sea. Commer. Fish. Rev. 30(7): 39-41.

Crawford, Ladell, and Roland Finch.
Quality changes in albacore tuna during storage on ice and in refrigerated sea water. Food Technol. 22(10): 87-91.

Dassow, J. A.
Characteristics of frozen shellfish: Factors affecting quality changes during freezing and storage. Part 1. Crabs and lobsters. *In* Donald K. Tressler, Wallace B. Van Arsdel, and Michael J. Copley (editors), The freezing preservation of foods, 4th ed., 2: 197-208. Avi Publishing Co., Westport, Conn.

Preparation for freezing and freezing of shellfish: Part 1. Crabs and lobsters. *In* Donald K. Tressler, Wallace B. Van Arsdel, and Michael J. Copley (editors), The freezing preservation of foods, 4th ed., 3: 266-275. Avi Publishing Co., Westport, Conn.

Dubrow, David L.
Nutritive quality of fish protein concentrate (FPC): Effect of heating raw fish prior to solvent extraction. M.S. thesis, University of Maryland, College Park, Md., 72 pp.

Eklund, M. W.
Growth and toxin production of *Clostridium botulinum* type E, nonproteolytic B and F in nonirradiated and irradiated fisheries products in the temperature range of 38° to 50° F. Eighth Annu. AEC Food Irradiat. Contract. Meet, CONF-681006, pp. 43-55.

Subcommittee report on microbiology. Eighth Annu. AEC Food Irradiat. Contract. Meet., CONF-681006, pp. 265-274.

Eklund, M. W., and F. T. Poysky.
Growth and toxin production of *Clostridium botulinum* type E., nonproteolytic B, and F in nonirradiated and irradiated fisheries products in the temperature range of 38° to 50° F. U.S. AEC, Div. Biol. Med., Contract AT(49-7)-2442, Modif. 6, 70 pp.

Finch, Roland.
Seagoing recorder probes tuna temperatures. Instrumentation 21(3): 18-19.

The exploitation of the living resources of the California current: A food technologist's point of view. Calif. Coop. Oceanic Fish. Invest. Annu. Meet., 8 pp. [Processed.]

Fish Boat.
Upgrading a fishery—how it was done. The Fish Boat 13(8): 22-23. [Prepared by G. W. Fleihman, *Quality Control Specialist*, R. A. Grieg, *Chemist*, and J. A. Emerson, *Assistant Laboratory Director*, Bureau of Commercial Fisheries Technological Laboratory, Ann Arbor, Mich.]

Fish Business.
"BCF" activities report. Fish Business 3 (10): 7. [Prepared by Richard W. Nelson, *Chemist*, and John A. Dassow, *Assistant Laboratory Director*, Bureau of Commercial Fisheries Technological Laboratory, Seattle, Wash.]

Fleihman, G. W., R. A. Grieg, and J. A. Emerson.
See Fish Boat.

Gadbois, Donald F., Paul G. Scheurer, and Frederick J. King.
Analysis of saturated aldehydes by gas-liquid chromatography using methylolpthalimide for regeneration of their Girard-T derivatives. Anal. Chem. 40: 1362-1365.

Gould, Edith.
Malic enzyme: Evidence for two molecular forms in the sarcoplasm of fish skeletal muscle. J. Fish. Res. Bd. Can. 25: 1581-1589.

Graikoski, J. T., N. Kazanas, J. Watz, S. DuCharme, J. A. Emerson, and H. L. Seagran.
Irradiation preservation of freshwater fish. Annual report, April 15, 1966-April 14, 1967. U.S. AEC, Div. Tech. Inform., TID-24776, various pagination.

Groninger, H. S., and J. Spinelli.
EDTA inhibition of inosine monophosphate dephosphorylation in refrigerated fishery products. J. Agr. Food Chem. 16: 97-99.

Groninger, Herman S., and Kenneth R. Brandt.
Rapid method for the estimination of EDTA (ethylenediaminetetraacetic acid) in fish flesh and crab meat. Preprint published for U.S. Fish Wildl. Serv., Fish. Ind. Res. 4: 209-212.

Huff, John B.
Designing for lower food-irradiation costs. Isotop. Radiat. Technol. 6: 154-162.

Jones, Robert.
Use of sodium acid pyrophosphate to retain natural moisture and reduce struvite in canned king crab (*Paralithodes* spp.). U.S. Fish Wildl. Serv., Fish. Ind. Res. 4: 83-89.

Karrick, Neva L., and Claude E. Thurston.
Proximate composition and sodium and potassium contents of four species of tuna. U.S. Fish Wildl. Serv., Fish. Ind. Res. 4: 73-81.

Kaylor, John D.
Operations and progress of the marine products development irradiation. Seventh Annu. AEC Food Irradiat. Contract. Meet., CONF-670945, DID: AT(49-11)-1889, pp. 5-9.

Kazanas, Nuria.
Proteolytic activity of microorganisms isolated from freshwater fish. Appl. Microbiol. 16. 128-132.

Kazanas, N., and J. A. Emerson.
Effect of γ irradiation on the microflora of freshwater fish. III. Spoilage patterns and extension of refrigerated storage life of yellow perch fillets irradiated to 0.1 and 0.2 megarad. Appl. Microbiol. 16: 242-247.

Kifer, R. R., and W. L. Payne.
Selenium content of fish meal. Feedstuffs 40(35): 32.

Kifer, R. R., W. L. Payne, P. E. Bauersfeld, and M. E. Ambrose.
The nutritive content of Peruvian anchovy fish meal evaluated by chemical methods. Feedstuffs 40(35): 31-32.

Kifer, R. R., W. L. Payne, D. Miller, and M. E. Ambrose.
The nutritive content of menhaden (Brevoortia tyrannus and patronus) fish meal evaluated by chemical methods. Feedstuffs 40(2): 36.

King, F. J., and J. Holston.
Research on the chemistry of radiopasteurized seafoods. Seventh Annu. AEC Food Irradiat. Contract. Meet., CONF-670945, DID: AT(49-11)-2443, Modif. 3, pp. 77-81.

Research on the chemistry of radiopasteurized seafoods. *In* Status of the food irradiation program, Hearings before the Subcommittee on Research, Development, and Radiation of the Joint Committee on Atomic Energy, Congress of the United States, Ninetieth Congress, Second Session on Status of the Food Irradiation Program, July 18 and 30, 1968, pp. 289-293.

Krzeczkowski, Richard A.
Effect of gamma radiation on thiaminase activity in fresh-water fish. U.S. Fish Wildl. Serv., Fish. Ind. Res. 4: 133-138.

Love, Travis D.
Relation of temperature, time, and moisture to the production of aflatoxin in fish meal. U.S. Fish Wildl. Serv., Fish. Ind. Res. 4: 139-142.

Malins, Donald C.
Metabolism of glycerol ether-containing lipids in dogfish (*Squalus acanthias*). J. Lipid Res. 9: 687-692.

Medwadowski, B., J. Van der Veen, and H. S. Olcott.
Nature of residual lipids in menhaden fish protein concentrate. J. Amer. Oil Chem. Soc. 45: 709-710.

Mendelsohn, Joseph M., and Richard O. Brooke.
Radiation, processing and storage effects on the head gas components in clam meats. Food Technol. 33(9): 1162-1166.

Miyauchi, David.
Application of radiation-pasteurization processes to Pacific Coast fishery products. Eighth Annu. AEC Food Irradiat. Contract.

Miyauchi—Con.
Meet., CONF-681006, Contract DID: AT (49-11)-2058, pp. 29-35.

Radiation preservation of fish. Proc. 15th Annu. NWPPA Power Use Conf., Newport, Oreg., 5 pp.

Miyauchi, D., J. Spinelli, G. Pelroy, and M. A. Steinberg.
Radiation preservation of Pacific Coast fisheries products. Isotop. Radiat. Technol. 5: 136-141.

Miyauchi, David, John Spinelli, Gretchen Pelroy, Fuad Teeny, and John Seman.
Application of radiation-pasteurization processes to Pacific crab and flounder. U.S. AEC, Div. Tech. Inform., TID-24317, Contract AT(49-11)-2058, 136 pp.

Nelson, Richard W., and John A. Dassow.
See Fish Business.

Parker, Elliott T., Julius B. Bernsteinas, and John H. Green.
Increased recovery of psychrophilic bacteria by use of a new medium with lower solidifying temperature. Appl. Microbiol. 16: 1794.

Payne, Willie L[eonard].
An investigation of intestinal amino acids as a method to determine protein quality. Ph. D. Thesis, University of Maryland, College Park, Md., 155 pp.

Investigation of apparent amino acid digestibility as a method to determine protein quality. Proc. 1968 Md. Nutr. Conf. Feed Mfr., pp. 73-83.

Payne, W. L., G. F. Combs, R.R. Kifer, and D. G. Snyder.
Investigation of protein quality-ileal recovery of amino acids. Fed. Proc. 27: 1199-1203.

Peifer, James J.
Hypocholesterolemic effects of marine oils. U.S. Fish Wildl. Serv., Circ. 285, 16 pp. [Also *in* M. E. Stansby (editor), Fish oils; their chemistry, technology, stability, nutritional properties, and uses, pp. 322-361. Avi Publishing Co., Inc., Westport, Conn.]

Pelroy, Gretchen A., and John P. Seman, Jr.
Effect of storage temperature on the microflora of irradiated and nonirradiated vacuum-packaged petrale sole fillets. J. Milk Food Technol. 31: 231-236.

Peters, J[ohn] A.
The preparation for freezing and storage of shellfish: Part 3. Oysters, scallops, clams, and abalone. *In* Donald K. Tressler, Wallace B. Van Arsdel, and Michael J. Copley (editors), The freezing preservation of foods, 4th ed., 3: 289-294. Avi Publishing Co., Westport, Conn.

Characteristics of frozen shellfish: Factors affecting quality changes during freezing and storage. Part 3. Oysters, scallops, clams, and abalone. *In* Donald K. Tressler, Wallace B. Van Arsdel, and Michael J. Copley (editors), The freezing preservation of foods, 4th ed., 2: 216-223. Avi Publishing Co., Westport, Conn.

Peters, J. A., W. A. MacCallum, W. J. Dyer, D. R. Idler, J. W. Slavin, J. P. Lane, D. I. Fraser, and E. J. Laishley.
Effect of stage of rigor and of freezing-thawing processes on storage quality of refrozen cod. J. Fish. Res. Bd. Can. 25: 299-320.

Plastino, Helen E., and Mary S. Fukuyama.
Author index of publications and addresses - 1966, Bureau of Commercial Fisheries Branch of Technology and Branch of Reports (Seattle). U.S. Fish Wildl. Serv., Fish. Ind. Res. 4: 151-164.

Porter, R. W.
The acid-soluble nucleotides in king crab muscle. J. Food Sci. 33: 311-314.

Robisch, Paul A., and Edward H. Gruger, Jr.
Variation in the fatty acid composition of Pacific herring (*Clupea harengus pallisi*) and in Alaska during 1964 and 1965. U.S. Fish Wildl. Serv., Fish. Ind. Res. 4: 143-150.

Ronsivalli, L. J., V. G. Ampola, F. J. King, and J. A. Holston.
Study of irradiated-pasteurized fishery products. U.S. AEC Div. Tech. Inform., TID-24257, Contract AT(49-11)-1889, 81 pp.

Ronsivalli, L. J., and J. Holston.
Study of irradiated-pasteurized fishery products. Seventh Annu. AEC Food Irradiat. Contract Meet., CONF-670945, DID: AT (49-11)-1889, pp. 2-4.

Ronsivalli, L. J., F. J. King, J. M. Mendelsohn, D. F. Gadbois, R. O. Brooke, and J. A. Holston.
Chemistry of radiopasteurized seafoods. U.S. AEC, Div. Tech. Inform., TID 24633, Contract AT (49-11)-2443, Modif. 3, pp. 1-39.

Roubal, William T.
An easily constructed flow cuvet, a modular assembly for automated chemical analyses. J. Chem. Educ. 45: 439.

Sanford, F. Bruce.
Heading-introduction technique. U.S. Fish Wildl. Serv., Circ. 283, 32 pp.

Organizing the technical article. U.S. Fish Wildl. Serv., Circ. 269, 41 pp.

Scheurer, Paul G.
Penetration gradients of sodium nitrite and sodium tripolyphosphate in haddock fillets. J. Food Sci. 33: 504-506.

Slavin, J. W., and J. A. Dassow.
Fishery products. *In* ASHRAE guide and data book - application, Ch. 27 (rev.), pp. 325-338. American Society of Heating, Refrigerating, and Air-Conditioning, Inc., New York.

Spinelli, John, and David Miyauchi.
Irradiation of Pacific Coast fish and shellfish. 5. The effort of 5' inosine monophosphate on the flavor of irradiated fish fillets. Food Technol. 22 (6): 123-125.

Spinelli, John, and Dave Wieg.
Reducing drip loss in fish fillets. Canner/Packer, pp. 28-29.

Stansby, M. E., George Kudo, and Alice Hall.
Chemical spoilage pattern of grayfish. Food Technol. 22 (6): 107-110.

Steinberg, Maynard A.
Discussion. *In* Jan-Olaf Traung and Lars-Ola Engvall (compilers), Research craft conference: 2, vol. II, Pt. 1-2, pp. 22-23. Food and Agricultural Organization of the United Nations, Rome, Italy.

Session IV, Rapporteur's report: Processing needs. *In* De Witt Gilbert (editor), The future of the fishing industry of the United States, Univ. Wash. Publ. Fish., New Series, 4: 203-204. University of Washington Press, Seattle, Wash.

Steinberg, Maynard A., and J. A. Dassow.
Preservation of the catch. *In* Jan-Olaf Traung and Lars-Ola Engvall (compilers), Research craft conference: 2, vol. I, Pt. 1/IV, pp. 1-6. Food and Agricultural Organization of the United Nations, Rome, Italy.

Stillings, B. R.
See Wohl, Michael G., and Robert S. Goodhart (editors).

Stillings, Bruce R., and Donald G. Snyder.
Bounty from the sea, or dine with King Neptune. Proc. Chemurg. Counc., 30th Annu. Conf.

Stout, Virginia F.
Pesticide levels in fish of the Northeast Pacific. Bull. Environ. Contam. Toxicol. 3: 240-246.

Thompson, Harold C., and Mary H. Thompson.
Isolation and amino acid composition of the collagen of white shrimp (*Penaeus setiferous*) - I. Comp. Biochem. Physiol. 27 (1): 127-132.

Waters, Melvin E., and M. K. Hamby.
Effect of nitrofurans and chloretracycline on microorganisms associated with shrimp. Appl. Microbiol. 17: 21-25.

Williams-Walls, N. J.
Clostridium botulinum type F: Isolation from crabs. Science 162 (3851): 375-376.

Wohl, Michael G., and Robert S. Goodhart (editors).
Protein supplements and foods. *In* Michael G. Wohl and Robert S. Goodhart (editors), Modern nutrition in health and disease, 4th ed., pp. 1199-1201. Lea & Febiger, Philadelphia, Pa. [Prepared by Bruce R. Stillings, *Nutritionist*, Bureau of Commercial Fisheries Technological Laboratory, College Park, Md.]

ADDRESSES[1]

Division of Food Science
Washington, D.C.

Allen, Harold B.
Quality improvement through mandatory continuous inspection and technical assistance to the fishing industry.
Regional and Area Directors, Meeting, Frederick, Md., Mar. 13.

Brooker, James R.
Sanitation discrepancies noted in USDI inspected breaded shrimp plants.
Food and Drug Administration sponsored Breaded Shrimp Workshop, Brownsville, Tex., and Tampa, Fla., Nov. 9 and 13.

Durrant, Norman W.
The nutrient content of turtle grass (*Thalassia testudinum*).
Sixth International Seaweed Symposium, Santiago de Compostela, Spain, Sept. 9-13.

Finch, Roland A.
FPC, the state of the art.
Conference on Investment in the Oceans, New York City, N.Y., Dec.

Technological Laboratory
College Park, Maryland

Ambrose, Mary.
Associate referee report on protein digestibility of fish meals.
82d Annual Meeting of the Association of Official Analytical Chemists, Washington, D.C., Oct. 14-17.

Semi-micro method for determining total lipids in fish meal.
82d Annual Meeting of the Association of Official Analytical Chemists, Washington, D.C., Oct. 14-17.

Brown, Norman L.
Protein from fish.
Northeast Section of the American Oil Chemists' Society 7th Annual Symposium, Newark, N.J., Apr. 23.

[1] If you wish more information on any of the addresses, the directory is on page 163. Please give complete citation as shown in each address.

Hammerle, Olivia A.
FPC in foods and nutrition.
First Food from the Sea—Industry Conference, Washington, D.C., Jan. 25-26.

Fish protein concentrate as an industry.
Symposium "Industry's Future in the Ocean," Miami, Fla., Mar. 4-5.

Kifer, Robert R.
Chemical composition and biological evaluation of fish meal.
World Conference on Animal Production, University of Maryland, College Park, Md., July 14-20.

Knobl, George M., Jr.
Progress towards commercialization of fish protein concentrate.
13th Atlantic Fisheries Technological Conference, St. John's, Newfoundland, Sept. 15-18.

Semi-micro method for determining total lipids in fish meal.
13th Atlantic Fisheries Technological Conference, St. John's, Newfoundland, Sept. 15-18.

Payne, Willie L.
An investigation of protein quality-ileal recovery of amino acids.
Federation of American Societies for Experimental Biology, Atlantic City, N.J., Apr. 15-20.

Investigation of apparent amino acid digestibility as a method to determine protein quality.
1968 Maryland Nutrition Conference, Washington, D.C., Mar. 27-29.

Sidwell, Virginia D., and B. R. Stillings.
Fish protein concentrate: Its production, nutritional quality, and use in foods.
Meeting of American Association of Cereal Chemists, New York, City, N.Y., Sept. 10-12.

Snyder, Donald G.
A history of commercial development.
Symposium "Industry's Future in the Ocean," Miami, Fla., Mar. 5.

Common interests of the Bureau of Commercial Fisheries and United States industrial firms in the commercial development of fish protein concentrate.
Governor's Symposium on Fish Protein Concentrate, New Bedford, Mass., Apr. 29.

Stillings, Bruce R.
Enzymatic and microbiological alterations of marine proteins.
Western Hemisphere Nutrition Congress II, San Juan, P.R., Aug. 26-29.

Bounty from the sea, or dine with King Neptune.
Chemurgic Council 30th Annual Conference, Chicago, Ill., Oct. 10-11.

Division of Publications
Seattle, Washington

Sanford, F. Bruce.
Organizing the technical article.
Eighth Annual Short Course in Technical Writing, University of Washington, Seattle, Wash., Sept. 25.

Heading-introduction technique.
Eighth Annual Short Course in Technical Writing, University of Washington, Seatle, Wash., Sept. 26.

Organizing the research report.
Eighth Annual Short Course in Technical Writing, University of Washington, Seattle, Wash., Sept. 27.

The use of 35-mm. slides in the illustration of technical talks.
Society of Technical Writers and Publishers, Seattle, Wash., Oct. 1.

Short course in technical writing.
Bureau of Commercial Fisheries Technological Laboratory, College Park, Md., Dec. 2-6.

Bureau of Commercial Fisheries Technological Laboratory, Gloucester, Mass., Dec. 9-10.

Bureau of Commercial Fisheries Technological Laboratory, Ann Arbor, Mich., Dec. 11-13.

Technological Laboratory
Gloucester, Massachusetts

Holston, John A.
Marine products technology and development.
Eighth Annual AEC Contractors' Meeting, Washington, D.C., Oct. 16.

Kaylor, John D.
Operation and progress of the marine products development irradiator. (Contract AT(49-11)-1889.)
Hearings before the Subcommittee on Research, Development and Radiation of the Joint Committee on Atomic Energy. Congress of the United States, 90th Congress, 2d Session on Status of the Food Irradiation Program, Washington, D.C., July 18 and 30.

King, Frederick J.
Significance of dimethyl sulfide to odor of soft-shell clams.
Institute of Food Technologists Annual Meeting, Philadelphia, Pa., May 22.

Radiopasteurization of fishery products - radiation chemistry.
Eighth Annual AEC Contractors' Meeting, Washington, D.C., Oct. 16.

Learson, Robert J.
Collaborative study of a rapid electrophoretic method for fish species identification.
82d Annual Meeting of the Association of Official Analytical Chemists, Washington, D.C., Oct. 15.

Mendelsohn, Joseph M.
Opening oysters using microwave energy.
Oyster Institute of North America, Alexandria, Va., July 17.

Ronsivalli, Louis J., and J. A. Holston.
Radiopasteurization of fishery products - radiation technology.
Eighth Annual AEC Contractors' Meeting, Washington, D.C., Oct. 16.

Study of irradiated-pasteurized fishery products. (Contract AT(49-11)-1889.)
Hearings before the Subcommittee on Research, Development and Radiation of the Joint Committee on Atomic Energy.

Ronsivalli and Holston—Con.
Congress of the United States, 90th Congress, 2d Session on Status of the Food Irradiation Program, Washington, D.C., July 18 and 30.

Technological Laboratory
Pascagoula, Mississippi

Thompson, Mary H.
Green discoloration in frozen raw breaded shrimp.
13th Atlantic Fisheries Technological Conference, St. John's, Newfoundland, Sept. 15-18.

Collaborative study of the determination of sodium and potassium in fish and other marine products.
82d Annual Meeting of the Association of Official Analytical Chemist, Washington, D. C., Oct. 14-17.

Technological Laboratory
Seattle, Washington

Eklund, Melvin W.
Bacteriophages from mitomycin C induced lysis of *Clostridium botulinum* types A, B, E, and F and nontoxigenic type E.
UJNR (United States-Japan Cooperation on Development of Natural Resources) Conference on Toxic Microorganisms, Honolulu, Hawaii, Oct. 8.

Growth and toxin production of *Clostridium botulinum* type E, nonproteolytic B and F in nonirradiated and irradiated fisheries products in the temperature range of 38° to 50° F.
Eighth Annual AEC Food Irradiation Contractors' Meeting, Washington, D.C., Oct. 16.

Subcommittee report on microbiology.
Meeting of Microbiology Subcommittee, Eighth Annual AEC Food Irradiation Contractors' Meeting, Washington, D.C., Oct. 17.

Miyauchi, David.
Radiation preservation of fish.
Fifteenth Annual Power Use Conference of the Northwest Public Power Association, Newport, Oreg., Sept. 11.

Application of radiation-pasteurization processes to Pacific coast fishery products.
Eighth Annual AEC Food Irradiation Contractors' Meeting, Washington, D.C., Oct. 17.

Nelson, Richard W.
Application of controlled-atmosphere storage to Pacific Coast seafoods.
13th Atlantic Fisheries Technological Conference, St. John's, Newfoundland, Sept. 17. [Presented by Richard A. Robohm of the Bureau of Commercial Fisheries Technological Laboratory, Ann Arbor, Mich.]

Spinelli, John.
FPC processing by wet fractionation.
National Academy of Sciences Meeting, Seattle, Wash., Mar. 21.

Steinberg, Maynard A.
The effects of FPC on present and future markets for fish oils.
Meeting of National Fish Meal and Oil Association, Norfolk, Va., Feb. 19.

Annual Meeting of Pacific Fisheries Technologists, Victoria, British Columbia, Mar. 19.

The hazards of Salmonella and Clostridia in the fishing industry.
Meeting of Salmon Trollers Association, Portland, Oreg., Feb. 23.

Session IV Rapporteur's report: Processing needs.
Conference on the Future of the Fishing Industry of the United States, University of Washington, College of Fisheries, Seattle, Wash., Mar. 24-27.

Fish as food.
Meeting of Fisheries Interim Committee, Seattle, Wash., Apr. 12.

Potential for utilization of fish oils in feeding fish.
Bureau Meeting with Technical Committee of National Fish Meal and Oil Association, Washington, D.C., Oct. 30-31.

LISTS OF PUBLICATIONS FOR PREVIOUS YEARS

1955-61 Fishery Industrial Research 2(2): 43-48.

1962 Fishery Leaflet 560. (Copies available from the Bureau of Commercial Fisheries Publications, U.S. Fish and Wildlife Service, 1801 North Moore Street, Arlington, Virginia 22209.)

1963 Fishery Leaflet 572. Copies available from the Bureau of Commercial Fisheries Publications, U.S. Fish and Wildlife Service, 1801 North Moore Street, Arlington, Virginia 22209.)

1964 Fishery Industrial Research 3(1): 9-21.

1965 Fishery Industrial Research 3(4): 47-58.

1966 Fishery Industrial Research 4:151-164.

1967 Fishery Industrial Research 5: 215-230.

DIRECTORY

Bureau of Commercial Fisheries
Technological Laboratory
P.O. Box 128
College Park, Maryland 20740

Bureau of Commercial Fisheries
Technological Laboratory
Emerson Avenue
Gloucester, Massachusetts 01931

Bureau of Commercial Fisheries
Technological Laboratory
239 Frederick Street (P.O. Drawer 1207)
Pascagoula, Mississippi 39567

Bureau of Commercial Fisheries
Technological Laboratory
2725 Montlake Boulevard East
Seattle, Washington 98102

Bureau of Commercial Fisheries
Division of Publications
Building 67, U.S. Naval Air Station
Seattle, Washington 98115

Bureau of Commercial Fisheries
Division of Food Science
U.S. Department of the Interior
Washington, D.C. 20240

MS. #2046

SUGGESTIONS TO AUTHORS WRITING FOR *FISHERY INDUSTRIAL RESEARCH*

by F. Bruce Sanford, Lena Baldwin, and Mary S. Fukuyama

A. APPROACH

Write your paper for a reader who has had advanced scientific training. Organize and write it in such a way that he can read it rapidly, yet understand it the first time through.

B. COMPONENTS OF THE PAPER

1. Title

Select a title that reveals the overall purpose of your research. When appropriate, include scientific names of species.

2. Abstract

Make the abstract semidescriptive: tell what the report is about, and end with a statement of your overall conclusion. (This conclusion will answer the question stated, or implied, by your overall purpose.) Keep the abstract short, but do not use the title of the paper as the assumed antecedent of otherwise irreferable pronouns.

3. Contents

Include a table of contents.

4. Introduction

In the introduction, (1) orient the reader to your overall purpose, (2) state the purpose explicitly, (3) orient the reader to the subpurposes, and (4) end with a listing of the subpurposes.

Include in each orienting discussion all the important words that will occur in the subsequent statement of purpose. Avoid unnecessary reviews and economic data.

When stating the overall purpose, include a word such as "purpose" so that the reader can quickly identify the statement for what it is.

5. Main Divisions

Do not use such generalized divisions as "Experimental." Instead, be specific by making the main divisions of the paper correspond to the main divisions of your research—Experiment I, Experiment II, and so on. Give each experiment a specific title so that the reader will gain immediate insight into the scope of the experiment.

For main divisions, do not use "Materials," "Procedures," and "Results" (except when, as is rare, your paper reports only a single unit of research, such as Experiment I); instead, use these headings for minor divisions. When you use them, consider the following suggestions:

a. **Materials and methods.**—Describe in detail the materials and the methods used in your first experiment. If the materials and methods used in succeeding experiments are similar to those in the first, merely describe the differences when you report the succeeding experiments.

If a method includes several closely consecutive steps, number them and write out the steps; use the active voice—for example, "In the separation of acids from the aqueous phase, the analyst:

1. Neutralized a 1-milliliter portion of the aqueous layer to a pH of 10 with 0.1 N NaOH.
2. Transferred the neutralized solution to Flask A.
3. Placed Flask A in a bath . . . ."

b. **Results.**—Report all numerical data in tables and graphs—avoid cluttering the text with numbers. In the discussion of results, do not repeat the data that are contained in the tables and graphs. Instead, analyze the data by pointing out significances and implications. Use summary tables; do not overwhelm the reader with unnecessary tables of raw data.

6. Conclusions

Draw conclusions from your results. Make sure that the overall conclusion and the subconclusions correspond with your overall purpose and subpurposes. Present the conclusions in logical sequence.

7. Summary

End the report with a summary. Make the summary quantitative, not merely descriptive. If the report is short, end it with "Summary and Conclusions." If it is long, separate the two.

8. Acknowledgment

Avoid titles of individuals—such as mister, doctor, or professor. Simply acknowledge the assistance received.

9. Literature Cited

Make your citations complete and accurate so the reader can find the original with ease. Follow the format used in *Fishery Industrial Research.*

C. MECHANICS

1. Abbreviations

Avoid abbreviations unless you have compelling reason to use them—for example, if you lack space in your tables. If you use abbreviations, use the ones standard in your discipline. End the abbreviation with a period. See the latest issue of *Fishery Industrial Research.*

2. English Usage, Punctuation, and Capitalization

Meticulously follow established practice in grammar, punctuation, and capitalization. For precise, forceful statements, use personal pronouns where appropriate and thereby avoid illogical constructions or ambiguities.

3. Headings

Use the system of headings shown in the latest edition of *Fishery Industrial Research.*

4. Numbers

Use Arabic numbers unless you have a compelling reason to use Roman numbers or to write the numbers out. See the latest issue of *Fishery Industrial Research.*

5. Tables and Graphs

a. **Tables.**—Number each table and give it a title. (The title, placed at the top of the table, is a brief statement of such applicable referents as the nature, classification, or chronology of the information presented, and the political division, geographical area, or physical plant to which the data refer. These points are sometimes referred to as the "what," "how classified," "when," and "where" of the table.) Do not place a period at the end of the title. When headings apply to information in more than 1 column, word them so that they reveal the meaning of the data in all columns covered. Place all units of measurement over figure columns, and underline. Separate all columns with vertical lines, but use horizontal lines and footnotes sparingly. Place each table on a separate page. See the latest issue of *Fishery Industrial Research.*

b. **Graphs.**—Number each graph. Place the title at the bottom of the graph, and end it with a period. In wording the title, follow the suggestions for titles of tables. Frame all 4 sides of the graph. Place tick marks on the inside of the frame at only the left and bottom sides unless you have compelling reason to do otherwise. Identify ordinate and abscissa; capitalize all letters in the identification. Place units of measurement in parentheses, and print them in lower case. Unless it clutters the graph, label each curve directly instead of using a legend or a key. Place each graph on a separate page. See the latest issue of *Fishery Industrial Research.*

CONTENTS

GPO 997-659

UNITED STATES
DEPARTMENT OF THE INTERIOR
U.S. FISH AND WILDLIFE SERVICE
BUREAU OF COMMERCIAL FISHERIES
OFFICE OF SCIENTIFIC PUBLICATIONS
BLDG. 67, NAVAL SUPPORT ACTIVITY
SEATTLE, WASHINGTON 98115

OFFICIAL BUSINESS

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF THE INT

Return this sheet to above address, if you do NOT wish to receive this material ☐, or if change of address is needed ☐ (indicate change and give ZIP Code).